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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC)

System Maintenance Analysis

DDG-37 CLASS COMPRESSED AIR SYSTEMS

SMA-37-204-551

REVIEW OF EXPERIENCE

June 1978

Prepared for
Director, Escort and Cruiser
Ship Logistic Division
Naval Sea Systems Command
Washington, D.C.
under Contract N00024-78-C-4062

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The goal of the Destroyer Engineered Operating Cycle (DDEOC) Program is to effect an early improvement in the material condition of ships, at an acceptable cost, while maintaining or increasing their operational availablility during an extended operating cycle. In support of this goal, System Maintenance Analyses (SMAs) are being conducted for selected systems and subsystems of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-

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FOREWORD

This report, the Review of Experience, documents the historical maintenance experience for the DDG-37 Class Compressed Air Systems, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program, under Navy Contract N00024-78-C-4062.

8-22-78 telecon w. LtCdr. D. Keller (Proj Mgr) NavSea-Code 934X; this report is for "Public Release".

SUMMARY

this

The goal of the Destroyer Engineered Operating Cycle (DDEOC) Program is to effect an early improvement in the material condition of ships, at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, System Maintenance Analyses (SMAs) are being conducted for selected systems and subsystems of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Compressed Air Systems.

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance program of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified maintenance problems. It also presents specific recommendations and a system maintenance policy for preventing or reducing the impact of problem occurrence while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The Compressed Air Systems ROE included an analysis of all available maintenance data sources. The documented maintenance experience of the system was reviewed through analysis of Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records. Initial findings from these sources were correlated with Planned Maintenance System (PMS) requirements, system alterations, and system technical manuals to identify maintenance problems. Ship surveys were conducted and discussions were held with appropriate technical codes to validate identified problem areas, identify undocumented maintenance problems, and determine the status of current and planned actions affecting the Systems.

All findings were evaluated, and appropriate conclusions were developed. Major conclusions resulting from the Review of Experience for the Compressed Air Systems are summarized as follows: ROE

include:

- Major repairs of the Compressed Air Systems will be required during Baseline Overhaul;
- Training in the operation, maintenance, and repair of the systems is inadequate; however, the DART Air Compressor Improvement Program is moving towards correcting this deficiency; (cont on p vi)

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- Class B Overhaul of system components will be required at each ROH, with Material Condition Assessment (MCA) performed between overhauls to identify necessary Class C repairs, until an adequate shipboard maintenance capability is developed.
- The systems are adequately supported by the Navy Supply System.
- Most system problems or parts replacements are nonrecurring maintenance items, consumable items (packing, gaskets, etc.), or routine upkeep; and
- Most compressor problems can be traced to excessive or inadequate cylinder lubrication, water leaks, or the need for additional or revised PMS actions (e.g., renew zinc anodes, inspect piston rings, inspect air suction and discharge valves, etc.).
- In many cases, there is no positive means for scheduling PMS actions that are based on compressor operating hours alone, since operating logs are not maintained nor are elapsed-time meters installed on all air compressors.
- Even though the Worthington oil-free low pressure air compressor has experienced about twice the per-operating-year maintenance burden of the air compressor it replaces, most of the problems reported to date do not appear to be Class-wide.
- After the air compressors, the dehydrators represent the weak link in the Compressed Air Systems, particularly those which supply the Electronics Dry Air System.
- The "mini-lube" modification kit can significantly improve the service of older Worthington high pressure air compressors.
- The decision to replace the present oil-lubricated high pressure air compressors with an oil-free type should be reconsidered in light of this analysis.

Reliable operation of the Compressed Air Systems can be expected during the extended operating cycle if all major components are overhauled, the recommended ShipAlts are accomplished, PMS is modified as recommended, the recommended spares are supplied, and additional training is provided in the areas of system operations, maintenance, and repair. Specific recommendations resulting from this analysis are listed in Table S-1.

Table S-1. (continued)	
Component	**Recommendation**
Planned Maintenance System (PMS) Changes	
High Pressure Air Compressor	Develop a PMS action to clean and inspect the 1st, 2nd, 3rd, and 4th stage air compressor piston rings every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier (APLs 061900183 and 061900266 only).
	Develop a PMS action to inspect the 4th stage seal assembly after every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier (APL 061900338 only).
	Change the periodicity of MRC R-6 (84-E45K-N, Clean and Inspect Cylinder Lubrication Check Valves) to every 1000 hours of compressor operation or every 45 calendar months, whichever occurs earlier.
	Change the periodicity of MRC R-2 (27-L48D-N, Clean and Inspect 3rd and 4th Stage Valve Assemblies) to every 1000 hours of compressor operation or 45 calendar months, whichever occurs earlier (APLs 061900183 and 061900266 only).
	Develop a PMS action to inspect and renew, as necessary, the air compressor zinc anodes every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.
Cooling Water Shut-Off Valve	Change the periodicity of MRC R-11 (84-E45N-Y, Inspect Cooling Water Shut-Off Valve) to every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.
Air Line Filter	Change periodicity of MRC R-12 (36-J76D-Y, Renew Element in High Pressure Air Line Filter) annually or after 200 hours of operation, whichever occurs earlier.
Air System	Develop a PMS action to inspect air system for corrosion or damage every 6 months.
Industrial Facility Improvements	
None	
IMA Improvements	
None	
Integrated Logistic Support (ILS) Improvements	
Low and High Pressure Air Compressors	Provide increased operator training at the shipboard level.
	Establish air compressor maintenance courses at the Fleet Training Center level.
	Place additional emphasis on compressed air system operation at MM and BT "A" School.
Low Pressure Air Compressor	Ensure that information on the proper replacement air intake filter element is known at the ship level.
	Revise the technical manual for the Worthington Oil-Free Air Compressors (NAVSHIPS 0949-055-9010) to include more information on system details and equipment troubleshooting.
Low Pressure Air Dehydrators (Type III)	Either update the NAVSHIPS *Technical News* article "Modifying and Operating Dehydrators" and republish it in the *NAVSEA Journal* or condense it and release it to the Fleet as a Naval message.
High Pressure Air Compressor	Revise APL 061900338 to provide additional parts support and increased support depth (i.e., 4th stage sleeves and sleeve followers and zinc anodes).
	Modify the EOSS procedures for the high pressure air compressor to add a step to check the cylinder lubricant's flow rate (HPAC/013).
	Advise compressor operating personnel of the recommended cylinder oiling rates.
	Revise APL 882240420 to increase the on-board allowance of O-rings.
	Revise APLs 061900183 and 061900266 to add an allowance of zinc anodes.
High Pressure Air Dehydrators	Provide ships of the Class having Kahn and Company high pressure air dehydrators (APL 440130022) with technical manuals for these units.
High Pressure Air Separator Flasks	Increase the availability of replacement high pressure air separator flasks that meet MIL-F-22606.
Cooling Water Shut-Off Valve	Monitor the operation of the most recent design of this valve (D53X) to determine if the latest changes have improved the valve's performance.
	Monitor the tests at NSRDC to determine if the "modified" cooling water shut-off valve is an improvement over the existing valves. If the valve is a significant improvement, modify all valves via AER as they fail.
Air System	Develop Material Condition Assessment (MCA) procedures for the Compressed Air Systems.

Table S-1. SUMMARY OF ROE RECOMMENDATIONS	
Component	**Recommendation**
Baseline Overhaul Requirements	
A. Repairs and Overhauls	
Low Pressure Air Compressors	Perform Class B Overhaul of 4 Worthington oil-free compressors.
Low Pressure Air Dehydrators (Type III)	Perform Class B overhaul of 2 Howell Laboratories dehydrators; overhaul to include replacement of ball check valves, if dehydrators are not replaced by ShipAlts.
Low Pressure Air Dehydrators (Type I)	Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressors/ Install Dryers) to determine if false temperature indication and alarm problem exists; make necessary corrections.
Low Pressure Air Flasks	Remove, clean, test, preserve, and reinstall low pressure accumulator air flasks.
High Pressure Air Compressors	Perform Class B Overhaul of 2 Worthington air compressors; overhaul to include installation of "mini-lube" modification kit, as applicable.
	Install an automatic operating back-pressure valve in the air piping system between the air compressor and the moisture separator if not already installed (APL 061900338 only).
	Provide recommended on-board spares during SOAP, if not previously provided.
High Pressure Air Dehydrators (Type II)	Perform Class B Overhaul of 2 installed air dehydrators.
High Pressure Air Flasks	Remove, clean, inspect, and reinstall high pressure air flasks. (Depending on the dates of the last inspection, this could include up to 5 flasks.)
High Pressure Air Separator Flasks	Remove, clean, inspect 2 air separator flasks; replace those which are obsolete.
Air System Piping (L.P. and H.P.)	Inspect air system piping for oil contamination and for external corrosion or damage; make necessary repairs and test.
B. Alterations	
Low Pressure Air Compressor	Accomplish ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/Install Dryers) if not already completed.
Low Pressure Air Dehydrators (Type III)	Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit) if dehydrators are not replaced.
	Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryers with Type II) as applicable.
High Pressure Air Compressors	Accomplish ShipAlt DLG-6-0184K (Install Elapsed Time Meter and Events Indicator on H.P.A.C.) if not already completed.
	Accomplish lubricator low-oil-level shutdown device ShipAlt when it is developed.
Air Line Filters	Accomplish air-line filter replacement ShipAlt when it is developed.
Intracycle Maintenance Requirements	
All Equipments of the Compressed Air Systems	Accomplish existing PMS requirements as modified by recommendations of this report. Accomplish MCA procedures to identify necessary Class C repairs.
Follow-On ROH Requirements	
Low Pressure Air Compressors	Perform Class B Overhaul of 4 Worthington oil-free air compressors.
Low Pressure Air Dehydrators (Type I)	Perform Class C repairs to 4 Type I air dehydrators.
Low Pressure Air Dehydrators	Perform Class C repairs to 2 Type II or 2 Type III air dehydrators.
High Pressure Air Compressors	Perform Class B Overhaul of 2 high pressure air compressors.
High Pressure Air Dehydrators (Type II)	Perform Class C repairs of 2 Type II air dehydrators.
Air System Flask and Separators	Remove, clean, test, preserve, and reinstall air system flasks and separators.
Air System Piping	Inspect air system piping for oil contamination and for external corrosion or damage, including leaking valves; make necessary repairs and test.
Reliability and Maintainability Improvements	
Low and High Pressure Air Compressors	Develop standard operating logs and provide to ships.
	Install elapsed-time meters and events indicators.
Low Pressure Air Dehydrators (Type III) (if not replaced by ShipAlt)	Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit).
	Replace the Polyethylene Ball Check Valves (via AER).
	Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryer with Type II) as applicable.
	Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressors/ Install Dryers) to determine if false temperature indication and alarm exists.
High Pressure Air Compressors	Install "mini-lube" modification kit. Install automatic operating back-pressure valve.
	Develop ShipAlt to install an automatic compressor shutdown device controlled by the oil level in the cylinder lubricator oil reservoir.
Air Line Filter	Develop ShipAlt to replace current air-line filter with unit that requires less effort to change filter elements.

(continued)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In support of the Destroyer Engineered Operating Cycle (DDEOC) Program, sponsored by NAVSEA 934X, System Maintenance Analyses (SMAs) are being conducted on selected systems and subsystems of program-designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Compressed Air Systems, which were specifically selected for analysis because equipments of these systems are on the DDG-37 Class Maintenance Critical Equipment List.

1.2 PURPOSE AND SCOPE

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance programs of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified problems. It also presents specific recommendations and a system maintenance policy directed toward preventing or reducing the impact of problem occurrence while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The analysis documented herein is specifically applicable to the Compressed Air Systems of the DDG-37 Class ships. Only those system components that had been installed or were on board ship as of the fourth quarter of Fiscal Year 1977 were considered. The analysis used all available documented data sources from which system maintenance problems could be identified and studied. These included Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records, in addition to Planned Maintenance System (PMS) requirements data, system alteration documentation, and system technical manuals. Sources of undocumented data employed in this analysis included discussions with Ship's Force and other cognizant technical personnel.

1.3 SYSTEM FUNCTION AND BOUNDARIES

The DDG-37 Class Compressed Air Systems, as described in this report, encompass the Ship Service (Low Pressure) Air System and the High Pressure Air System.

The Ship Service (Low Pressure) Air System is a "single main" system that provides air for service connections with hose outlets (including special service connections in machinery spaces and workshops), and for operation of the following: (1) laundry presses, tank level-indicating system, (3) missile-handling equipment, (4) combustion control air system, (5) torpedo hoisting gear, and (6) remote shutdown of emergency diesel generators. For purposes of this study, the Ship Service (Low Pressure) Air System includes all system equipments and components starting with the low pressure air compressors and extending through the dehydrators for the Dry Air System and the air-reducing stations for the Control Air System.

The Ship Service (Low Pressure) Air System itself is supplied by either five Worthington Class CC (50 cfm at 100 psi) or four Worthington Class S (100 cfm at 125 psi) motor-driven low pressure air compressors.

The High Pressure Air System is also a "single main" system that provides air for the following purposes: (1) charging and servicing Mk 32 torpedo tubes, (2) supplementary supply for Ship Service Air System, (3) missile air service -- both for dud jettison and missile checkout, (4) 5"/54 caliber gun counter-recoil and gas ejection, and (5) ASROC Weapon services. For purposes of this study, the High Pressure Air System includes all system equipments and components starting with the high pressure air compressor and extending through the air-reducing stations and manifolds and the air flasks that supply air for the five purposes described above.

The High Pressure Air System itself is supplied by two Worthington Class B/BB (4.5 cfh at 4500 psi) motor-driven high pressure air compressors.

Major components of the Ship Service (Low Pressure) and the High Pressure Air Systems that were included in the analysis documented by this report are listed in Appendix A.

1.4 REPORT FORMAT

The remaining chapters of this report describe the analysis approach utilized (Chapter Two), briefly define significant system maintenance problems encountered and discuss potential problem solutions (Chapter Three), and summarize conclusions and recommendations derived from the analysis (Chapter Four). Specific analyses and evaluations supporting the results of this effort are included as appendixes to this report. A selected list of information sources precedes the appendixes.

CHAPTER TWO

APPROACH

Primary data sources used in performing the ROE for the DDG-37 Class Compressed Air Systems are identified in Section 1.2. The data were used to identify, define, and analyze maintenance problems that significantly affect the Compressed Air Systems maintenance program. A recommended system maintenance program for the extended operating cycle was formulated on the basis of the analysis results.

The analysis began at the component level at which Allowance Parts List (APL) numbers are assigned. It comprised the following major steps as described in Sections 2.1 through 2.3:

- Compiling relevant documented and undocumented maintenance history data.
- Analyzing these data to identify and define maintenance problems expected to have significant impact on maintenance of the systems.
- Recommending a specific course of action for solution of the system maintenance problems.

2.1 DATA COMPILATION

The analysis began with the compilation of a comprehensive data base of the maintenance history of the systems. The data file consisted of three key elements: an MDS data bank, a CASREP narrative summary, and a system overhaul experience summary. A library of ShipAlt information, technical manuals, bulletins, and related documents was also assembled. The MDS data bank was compiled by examining all MDS data reported for the DDG-37 Class from 1 January 1970 through 30 September 1977. CASREP information for the period 1 July 1973 through 30 September 1977 was reviewed. Overhaul information was obtained from DDG-37 Class Departure Reports, Repair Profiles, and authorized Ship Alteration and Repair Packages (SARPs).

2.2 MAINTENANCE PROBLEM DEFINITION

Potential maintenance problems associated with the systems and their components were identified by a screening process employing data obtained

from the above-described sources as well as from ship surveys, discussions with Navy technical personnel, and, when appropriate, NAVSEA special-interest programs.

MDS data constituted the initial and primary source of information used in the screening process. This data base includes all part and labor records, as well as narrative material describing maintenance actions reported against system components. Maintenance actions are represented by Job Control Numbers (JCN). The purpose of the first step in the screening process was to identify the maintenance actions that had been reported against components of the systems under investigation.

Computer-assisted analysis quantified the man-hour and part-expenditure burdens incurred for each component, not only for the selected components individually but also, as appropriate, for each generic class of components. Individual components or component classes that had contributed significantly to the systems' maintenance burden were selected for the analysis described below. Components were also selected for analysis if they had generated a significant number of CASREPs or if other sources of information (e.g., ship surveys or overhaul experience) disclosed significant concern regarding maintenance problems or the maintenance programs for the components.

Detailed analysis of the selected components was directed toward defining each maintenance problem in terms of several specific factors: the effect of the problem on the component and system, the interval between occurrences of the problem, the redundancy of the affected component within the system, the criticality of the component to the system, the resources required to perform the maintenance necessary to correct the problem, and the expected component or system downtime.

2.3 ANALYSIS OF COMPONENT PROBLEMS AND DEFINITION OF SOLUTIONS

Once the component problems and their causes were identified, solutions were sought by examining each problem in relation to the extent to which it was recognized and its susceptibility to established types of corrective action. These analysis criteria are expressed in the following questions:

- Is the problem known to the Navy technical community and has a solution been proposed or established?
- Will a design change reduce or eliminate the problem?
- Is the problem PMS-related? Can it be reduced or eliminated by changes to PMS? (These changes might include adding or deleting requirements, changing periodicity, or developing material condition assessment tests and procedures).
- Can the problem be reduced or eliminated by improving Ship's Force, Intermediate Maintenance Activity (IMA), or depot-level capabilities?

- Can the problem be reduced or eliminated by periodically performing restorative maintenance? Should this be accomplished at a Selected Restricted Availability (SRA) by Ship's Force, IMA, or depot-level facilities?
- Is the run-to-failure concept a viable maintenance strategy for the associated equipment?

An affirmative answer to any question resulted in analysis of the effects of the solution and in an estimate, when possible, of the cost to implement the solution. A negative answer prompted the analyst to go to the next question. After all the questions concerning an individual problem were asked, the alternative near-term and long-term solutions were evaluated and the most acceptable alternatives defined and documented as recommendations. "Near term" recommended solutions, as used in this report, are those which are likely to be and should be accomplished prior to or during the initial DDG-37 Class Baseline Overhauls. "Long term" recommended solutions are those which are not likely to be accomplished until some of or all of the DDG-37 Class Baseline Overhauls have been completed or pertain to intra-cycle maintenance.

The historical overhaul experience for all installations of each selected component was then correlated with the recommended problem solutions. An evaluation was made to establish the Baseline Overhaul, intra-cycle, and follow-on Regular Overhaul requirements for each selected component.

CHAPTER THREE

ANALYSIS RESULTS

3.1 OVERVIEW

This chapter presents the results of the Review of Experience of the Compressed Air Systems.

The Navy has determined that both the Ship Service (Low Pressure) and the High Pressure Air Systems have been imposing an unacceptable maintenance burden on Ship's Force. To help reduce this burden, the DART Air Compressor Improvement Program was established at NAVSEA in March 1971. It has evolved to the point where it is basically a replacement program in which oil-lubricated air compressors, both low pressure and high pressure, are replaced with new standardized oil-free air compressors. In addition to replacing air compressors, the DART Program is concerned with improving the associated logistics support of air compressors, including the development of air compressor operation and maintenance training courses.

The maintenance burden associated with compressed air systems has historically been related to cylinder lubrication, cooling systems, and condensate drain systems. Oil carry-over of cylinder-lubrication oil into the compressed air piping system has been the most prominent specific problem. To help eliminate the oil carry-over problems experienced with the Ship Service Air System, the Navy, since 1974, has been replacing the installed oil-lubricated low pressure air compressors with "oil-free" or nonlubricated low pressure air compressors. Under the current compressor replacement schedule, "oil-free" low pressure air compressors will have been installed in all ten ships of the DDG-37 Class by early 1979.

To correct this oil carry-over situation in the High Pressure Air System and at the same time to increase compressor reliability and decrease maintenance and downtime, many of the high pressure air compressors have been modified to a point where the manufacturer has classified them as "mini-lube" compressors. In addition to the changes modifying the installed high pressure air compressors, ShipAlt DDG-37-1206K, "Replace High Pressure Air Compressors", is being developed. This ShipAlt will replace the present oil-lubricated high pressure air compressors with an "oil-free" type; it is planned for installation in DDG-37 Class ships beginning with those entering overhaul during the fourth quarter of fiscal year 1979.

Data screening as described in Chapter Two resulted in the selection of seven components of the Compressed Air System -- three associated with the low pressure air system and four associated with the high pressure air system -- as the major maintenance-burden contributors. Table 3-1 summarizes the data for these components. One hundred thirty-one parts within the seven components were identified by the screening process as items requiring analysis. Usage data for these parts are presented in Appendix B.

CASREP analysis supported the MDS data screening performed in defining repetitive problems and significant maintenance actions. Appendix C summarizes the CASREPs submitted against components of the Compressed Air Systems by showing the percentage of the total number of CASREPs attributable to each system component and indicating the types of failures experienced. ShipAlts applicable to the Compressed Air Systems are summarized in Appendix D. The discussion of each system problem category and recommended solutions begins in Section 3.2.

Analysis of MDS narrative data and CASREP reports (see Appendix C) and discussions with NAVSEC and Fleet personnel indicate that except for a small number of items to be addressed in later sections, the Compressed Air Systems are generally reliable and adequately supported by the Navy Supply System. Most system problems or parts replacements involve nonrecurring maintenance items, consumable items (packing, gaskets, etc.), or routine upkeep.

3.2 GENERAL SYSTEM PROBLEMS

Analysis of the Compressed Air Systems identified three general problems that affect the overall performance of the systems and contribute to several specific problems (to be discussed in Sections 3.3 and 3.4). These general problems are lack of air compressor operating logs, lack of a positive means for determining compressor operating time, and inadequate crew training. These same general problems were also identified on FF-1052 Class ships. A brief discussion of each problem follows.

3.2.1 Lack of Air Compressor Operating Logs

Operating logs on compressor operation are not normally maintained. Without an operating log -- which records such items as compressor temperature, pressure, and oiling rates -- maintenance personnel are unable to detect operating trends or impending equipment problems. SMMSO states* that the use of log sheets containing definitive operating criteria can assist in the early detection of correctable air compressor problems and can give operating personnel a better understanding of the principles of compressor operation. Such logs should be developed and provided to all DDG-37 Class ships. A sample log of the recommended type is contained in the referenced SMMSO Benefit Recommendation.

*In Maintenance Benefit Recommendation No. 12-75, "High Pressure Air Compressor Overhaul Interval Extension".

Table 3-1. MDS DATA SUMMARY OF SELECTED COMPRESSED AIR SYSTEM APLS FOR DDG-37 CLASS

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population*	Total Ship Operating Time (Ship-Years)**	Ships Reported	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours/ Component Operating Year
Ship Service (LP) Air System												
061900179	Air Compressor Class CC	10	5	50	48.8	10	643	7,071	2,938	10,007	101,453	41.0
061900359	Air Compressor Class S	7	4	28	9.9	5	148	2,914	154	3,068	25,137	77.5
440300014	Dehydrator Fltr. Rfgt. 30 SCFM	8	2 or 4	18	46.1	8	82	422	67	489	14,740	4.7
						Totals	873	10,407	3,159	13,564	141,330	
High Pressure (HP) Air System												
061900183	Air Compressor Class B/BB	10	2	20	58.7 (061900183, 061900266, 061900338)	10	283	4,517	999	5,516	92,492	86.8 (061900183, 061900266, 061900338)
061900266	Air Compressor Class B/BB	7	1 or 2	8		7	202	2,919	836	3,805	46,768	
061900338	Air Compressor Class B/BB	5	1 or 2	7		5	91	560	314	874	19,862	
060050003	Lubricator MDL PS-4	10	2	20	-	4	5	14	0	14	1,943	-
						Totals	581	8,010	2,149	10,209	161,065	
Grand Totals							1454	18,417	5,308	23,773	302,395	
Totals Reported for All System APLs							2210	24,087	8,338	32,425	373,828	
Percent of Total Reported Accounted for By Selected APLs							66	76	64	73	81	

*The LP and HP Air Compressors are both being replaced or extensively modified. The component population shown is the highest population that existed at any time during the MDS data period.
**The term "Ship Operating Time" refers to the time since commissioning of a ship less the time spent in overhaul, fitting out, and post-shakedown availability. In those cases where compressor modification dates were not available, ship operating time could not be determined.

3.2.2 Determining Compressor Operating Hours

Elapsed-time or hour meters are not installed on all high pressure air compressors, even though PMS requirements must be addressed after a prescribed number of operating hours. Consequently, the PMS actions are scheduled when it is estimated that the appropriate operating time has elapsed; scheduling inconsistencies, of course, result. To overcome this problem, all ships of the class should be checked to ensure that time meters are installed. ShipAlt DLG-6-0184K provides for such installation. However, NAVSEA incorrectly lists this alteration as accomplished on all ships of the Class since the meters were not installed on one of the ships visited during this analysis. Ship's Force could install the devices in about one hour each. Time meters should be used in conjunction with calendar time because they will permit the collection of more detailed maintenance history information and will provide a means of scheduling PMS actions that take into account individual operating time differences between compressors on each ship.

3.2.3 Crew Training

There is currently very little formal crew training in the operation, maintenance, and repair of the air compressors. Training now consists of the presentation of basic introductory material at MM and BT "A" Schools, MM and BT maintenance courses at Fleet Training Centers, on-the-job instruction from personnel more experienced with the compressors or from technical support personnel who are aboard to assist in casualty correction, and study of the technical manual when a problem occurs. Such training methods do not normally provide the depth of instruction required to develop an adequate shipboard maintenance capability. It is recommended that a compressor maintenance course be established at the Fleet Training Center level and that increased emphasis be placed on system operation and maintenance at MM and BT "A" Schools.

3.2.4 Recommendations

The following near-term actions should be taken:

- Develop, and provide to DDG-37 Class ships, air compressor operating logs that contain definitive operating criteria.
- Ensure that elapsed-time meters are installed on the air compressors.
- Place additional emphasis at MM and BT "A" School on compressed air system operation and maintenance.

For the long term, air compressor maintenance courses should be established at the Fleet Training Center level.

3.3 SHIP SERVICE (LOW PRESSURE) AIR SYSTEM

The Ship Service (Low Pressure) Air System was initially supplied by five oil-lubricated Class CC (50 cfm at 100 psi) Worthington motor-driven air compressors (APL 061900179). Beginning in 1974, these air compressors

have been replaced, as ships enter overhaul, with four Class S (100 cfm at 125 psi) "oil-free" Worthington motor-driven air compressors (APL 061900359). To date, the new "oil-free" low pressure air compressors have been installed on all but three DDG-37 Class ships (DDG-39, -43, and -44). These three remaining ships are scheduled to receive the "oil-free" air compressors by February 1979. Since most of the oil-lubricated low pressure air compressors have already been removed and the remainder are scheduled for removal in the next 12 months, this report will not address the older compressor (APL 061900179).

Even though the average maintenance man-hours per component operating year (see Table 3-1) for the relatively new Worthington compressor is about twice that of the air compressor it replaces, most of the problems reported to date via MDS are unique problems that do not appear to occur Class-wide. For this reason, and because the longest any oil-free air compressor has been installed in a DDG-37 Class ship is less than three years (the majority having been aboard less than two years), the discussion of oil-free air compressor problems should be considered as presenting potential problem areas only.

The "oil-free" low pressure air compressor is a positive-displacement three-cylinder, W-Type, two-stage, single-acting reciprocating compressor. Pressurized oil-free air is produced by the compressor in nonlubricated compression chambers. These chambers are separated from the compressor crankcase by distance pieces (spacer cylinders). The distance pieces also house seal assemblies that prevent the oil used in the compressor crankcase from entering the compression chambers. Figure A-3 (Appendix A) presents a section view of the Worthington Class S air compressor.

Also included within the boundaries of the Ship Service (Low Pressure) Air System, for the purposes of this study, are the two Howell Laboratories Type III (refrigeration-desiccant) dehydrators, one acting as a standby or backup unit. These units are used to remove dirt and moisture from low pressure air before it is used in shipboard electronic equipment.

To date, the most significant problem area associated with the oil-free air compressors is the rapid wear of the compressor piston rings.

3.3.1 Excessive Piston Ring Wear

3.3.1.1 Background

The Worthington oil-free air compressor (APL 061900359) uses three aluminum hollow-type pistons with bronze-filled teflon rider rings installed on the lower groove of the two first-stage pistons and the single second-stage piston. The low pressure, or first-stage, piston assemblies use two compression rings; the high pressure, or second-stage, piston uses three compression rings. The rings are nonmetallic self-lubricating types that expand against the cylinder liner as they wear. All of the piston rings are made of bronze-filled teflon.

The piston assemblies are illustrated in Figure A-3 of Appendix A.

3.3.1.2 Discussion

Analysis of MDS parts replacement data and narratives, review of CASREP data, and discussions with Naval Ship Research and Development Center (NSRDC) personnel and Fleet personnel indicate that the most significant equipment problem with the oil-free low pressure air compressor reported to date is excessive piston ring wear (piston wearout after less than 5-6000 hours of compressor operation). The main contributors to excessive piston ring wear are entry of water into the compression cylinders and entry of dirt from the air suction inlet into the compression cylinders.

Water in the Compression Cylinders

Water can enter a compression cylinder through a leak in the compressor cooling system or through backup in the condensate drain system that carries over into the cylinders. In either case, it takes much more than a few drops of water to damage the teflon piston rings to a point where they will affect the operation of the air compressor. Water in the compression cylinders has the effect of washing from the cylinder walls the lubrication deposited by the teflon piston rings. This lubrication must then be replaced by the rings, contributing to the problem of rapid piston-ring wear. Water from a leaking compressor cooling system can be either distilled water from the compressor's self-contained cylinder cooling system or salt water from the ship's auxiliary machinery cooling water system entering the air system via the interstage cooler.

An indication that there may be a water leak in the self-contained cooling water system can be obtained from the operational check of the distilled water expansion tank before the compressor is started. If the tank is dry or if the water level is significantly lower than normal, there is probably a leak in the system that should be located before the compressor is operated. Another means of detecting a leak in the self-contained system or a leak from the auxiliary machinery cooling water system is to crack open the inter- and after-cooler separators' manual drain valves when first starting the air compressor to drain residual water from the system and to determine, by the amount of water drained, whether or not there is a cooling water system leak.

The problem of water backing up in the condensate drain system and entering the compression cylinders, according to MDS narratives and discussions with Fleet personnel, has been the result of a dual failure of the drain system's solenoid valve and the drain system's liquid-level safety-shutdown probe. Such dual failure is most likely an unusual case which will be confirmed when more Fleet operating experience has been gained. In the meantime, condensate drain system failure or operational problems can be identified by cracking open both separator manual drain valves after 11 minutes of air compressor loaded operation (the end of the first automatic condensate drain system cycle); if only one or two ounces of water flows out, there is no condensate backup problem.

No material or design change action is recommended to help correct these possible Class problem areas, because the current safety device and operational procedures are considered adequate. Instead, emphasis should be placed on the importance of the operator's following the approved air compressor Engineering Operational Sequencing System (EOSS) Procedures as a means of controlling these problems.

Entry of Dirt From Air Suction Inlet Into Compression Cylinders

Dirt entering the compression cylinders acts as an abrasive, wearing both the piston rings and the cylinder liners. The air compressor has two air filter silencers, one mounted on each first-stage cylinder head, to clean and muffle intake air drawn into the compressor. Each filter contains a cleanable or renewable element. If the filter element ruptures, both particles of the element and airborne dirt are allowed to reach the air compression chambers. The rupture problem is known to both the Navy and Worthington, and redesign has been undertaken to provide a finer element and to incorporate a stainless steel mesh to provide greater filter strength. As of April 1977, NAVSEA had determined that the new elements were not stocked in the Navy Supply System but were available from Worthinton on a limited basis. When the redesigned elements are ordered, the old Part Number (P/N 203066-826) should be used, with the requisition remarks section specifying "Filter with stainless steel mesh". Since corrective action is in progress, the only recommendation concerning the problem will be to ensure that information concerning the replacement elements has reached the ship level.

3.3.1.3 Recommendations

The following near-term actions should be taken:

- Reemphasize to operators of oil-free air compressors the need to follow the EOSS procedures, particularly those having to do with the cooling water systems and the condensate drain system.
- Ensure that the information on the proper replacement air intake filter element is known at the ship level.

One means of accomplishing these two recommendations would be to submit articles on the subjects to each TYCOM, to be published in their Fleet information bulletins (i.e., COMNAVSURFLANT's "Contact" and COMNAVSURFPAC's "Quarterly Information Bulletin").

3.3.2 Dehydrator (APL 440300014) Failure

3.3.2.1 Background

The dehydrators are self-contained, fully automatic units designed to remove water, oil, and solid contaminants from the low pressure air before it is supplied to shipboard electronic equipments. The dehydrators are

designed for continuous operation, with moisture removal achieved by cooling the incoming wet air in a refrigeration stage that removes about 90 percent of the moisture and then passing the air through a chamber of molecular sieve desiccant. To permit continuous operation, two chambers of desiccant are provided so that one chamber may be reactivated while the other is dehydrating the air stream. A desiccant chamber is reactivated by heating the desiccant. Figure 3-1 is a schematic flow diagram of this unit.

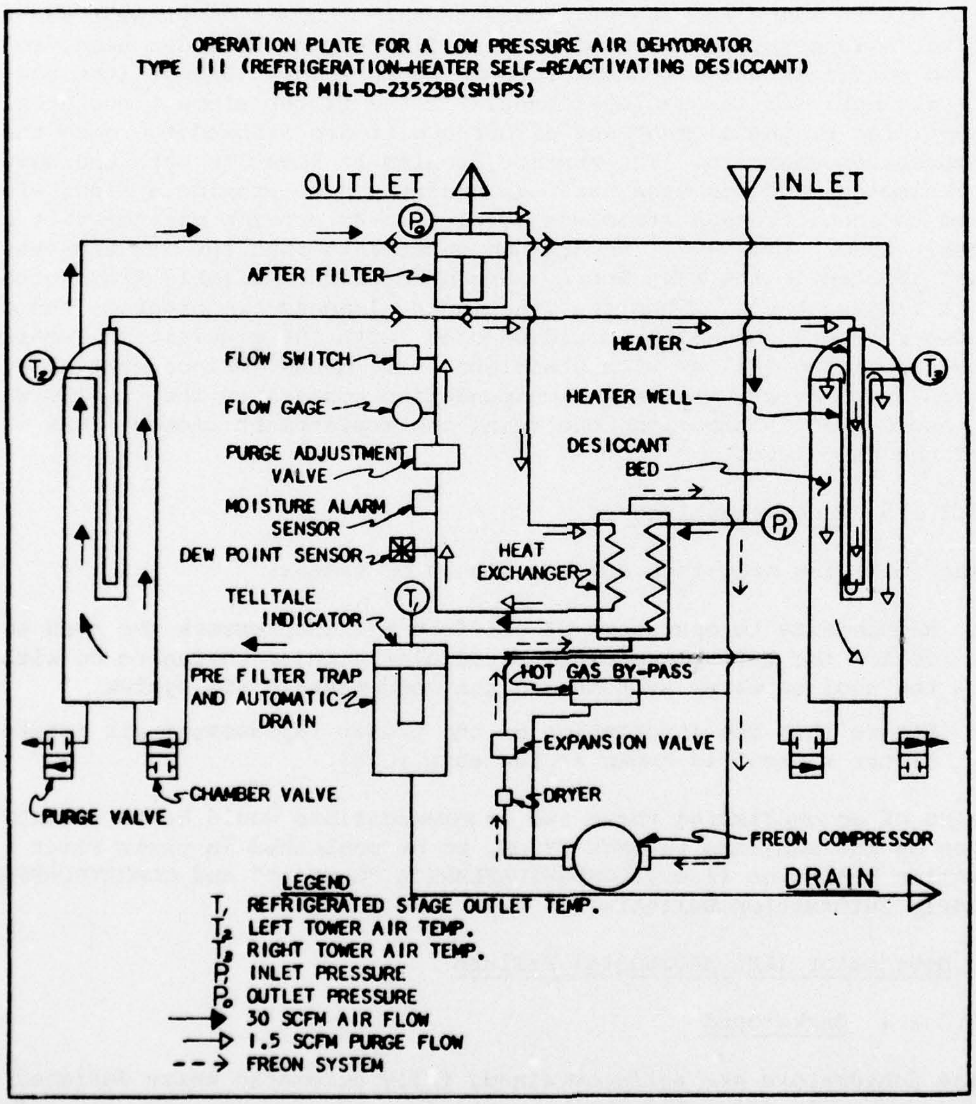

Figure 3-1. DEHYDRATOR (APL 44030014) SCHEMATIC FLOW DIAGRAM

3.3.2.2 Discussion

Analysis of MDS data and dehydrator CASREPs reveals that next to the air compressors, these dehydrators are the most problem-prone components of the Compressed Air Systems. Much of the corrective maintenance and parts replacement associated with the low pressure dehydrator is related to its purge air system, which is used for the reactivation of the desiccant chambers. As seen from Table B-1, Appendix B, the desiccant chamber's heater elements and the purge-air manifold assembly's ball-check valves have the highest parts replacement ratios of the items listed.

As currently designed, the purge air system's flow-monitoring devices (the flow gage and the flow switch) measure the air pressure in the system and convert it to a flow rate. With this method, a blockage in the purge air system, downstream of the flow switch, may not cause sufficient pressure drop to activate the flow switch to turn off the desiccant-chamber heater elements or cause any change on the air flow gage. Such blockage has occurred, according to MDS narratives, when the desiccant breaks down, causing desiccant powder to block the purge-air valve. ShipAlt DLG-6-1170D* (Air Dehydrator Modification Kit) should be installed to correct this design problem. This ShipAlt employs different flow gages and at the same time provides for additional reliability and maintainability improvements for the dehydrator (e.g., it adds an inlet separator to remove liquid water carry-over from the air compressor, installs a solenoid-operated inlet valve to prevent air from flowing through the unit when it is shut off, etc.). It may be obtained by using NSN 2H-4130-00-177-8774 at a cost of $2020. The kit can be installed by Ship's Force.

In addition to the purge-air system monitoring deficiencies, the purge-air flow switch itself can be improperly assembled, causing purge air system problems. The problem is described as follows in *NAVSHIPS Technical News:*

> "Reports indicate that, in some cases, the cut-off point of this device creeps upwards and enters the normal operating range of the dehydrator purge flow rate. The results were significant. The relay supplying 440V to the heater on regeneration was switched on and off continually, producing a popping sound and overheating its contacts to the point where they welded themselves together. The temperature controller could no longer cycle the heaters to maintain the correct temperature, and the heater burned itself out. In doing so, the temperature controller was driven off scale and its sensing unit was ruined."**

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*ShipAlt numbers, as used in this report, reflect the numbers as listed on the Ship Alteration Record; they are not changed to show the redesignation of DLG-6 Class ships to the new DDG-37 Class.

**Jones, R. and Goodhue, J. "Modifying and Operating Dehydrators", *NAVSHIPS Technical News*, August 1972, p. 22.

The improper assembly that causes the effects just described is installation of the small cylindrical brass follower, associated with the flow switch, in a reversed position. The correct way to install the follower is with its flat surface (rather than the hemispherical surface) contacting the flow-rate microswitch. Figure 3-2 shows the correct installation.

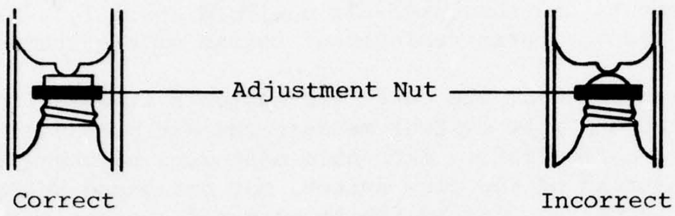

Figure 3-2. FLOW SWITCH FOLLOWER ASSEMBLY

To determine if the flow switch is assembled correctly, NAVSEC has recommended that after pressurizing the dehydrator:

> "[Use] a flashlight [to] illuminate the area behind the flow switch and observe the silhouette of the follower. Check for compliance with [Figure 3-2]. If it is incorrect, assure that there is no power to the unit and remove the microswitch. Reverse the follower and replace the microswitch. Purge flow will help to position the follower so that it may be grasped and removed. After reassembly, check the cut-off point of the flow switch and reset if necessary".*

Since MDS narratives and the parts usage data indicate that the problem of excessive heater element failure is still a Fleet problem, it is recommended either that the information contained in the *NAVSHIPS Technical News* article be updated (to include information on the dehydrator modification kit and the replacement ball check valve, as discussed below) and republished in the *NAVSEA Journal* or that it be condensed and released to the Fleet in a Naval message.

The second problem area concerns the material in the polyethylene ball check valves installed in the purge-air lines. Fleet experience has shown that the polyethylene ball frequently becomes deformed or marked in such a manner that it will not seal properly, thereby creating an unbalanced system. To overcome this problem with the ball check valve, the dehydrator manufacturer, Howell Laboratories, Inc., has replaced the valve assembly on later models with a new O-ring sealed poppet check valve. The replacement valve is a NU-PRO check valve (B-4C-1), available from Howell Laboratories under their part number HLI P/B 4730 at a cost of $8 to $10 each

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*Ibid.

(two valves are required per dehydrator). A sealing O-ring (NSN 9Z-5330-00-805-2966) is also required for each valve. These valves can be installed by Ship's Force, and it is recommended that NAVSEA and both Surface Type Commanders develop an AER for accomplishing this replacement.

Both of these recommendations are considered near-term solutions to the problems being experienced with the dehydrators. The long-term solution is to replace the dehydrators with an improved unit. This can be done by installing ShipAlt DLG-6-1098K (Electronics Dry Air Modifications). For ships on which the low pressure air systems are already divided into vital and nonvital service mains, but which still have the Type III dehydrators installed, the replacement can be effected by installing ShipAlt DDG-37-1177K (Replace Electronic Air Dryer with Type II).

3.3.2.3 Recommendations

The following near-term and long-term actions should be taken:

- Near Term
  - Authorize the accomplishment of ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit) for ships of the Class on which it has not already been installed.
  - Either update the *NAVSHIPS Technical News* article "Modifying and Operating Dehydrators" and republish it in the *NAVSEA Journal* or condense the article and release it to the Fleet as a Naval message (update to add information concerning the dehydrator modification kit and the replacement ball check valve).
  - Using Howell Laboratories P/N 4730, replace the installed dehydrator polyethylene ball check valves and sealing O-rings (replacement to be accomplished by AER).
- Long Term. Accomplish either ShipAlt DLG-6-1098K (Electronics Dry Air Modifications) or DDG-37-1177K (Replace Electronics Air Dryer with Type II).

3.3.3 Ship Service (Low Pressure) Air System -- Minor Maintenance Problems

Four minor maintenance problems were identified in the analysis of the Ship's Service (Low Pressure) Air System. They are related to surface inspection of the system, failure of air compressor cooling water shut-off valves, false temperature alarms on air dehydrators, and deficiencies in system technical manuals.

3.3.3.1 Surface Inspection of Low Pressure Air System

Good engineering practice as specified in Article 9490.151 of the NAVSHIPS Technical Manual requires that all air flasks, separators, and piping be given a surface inspection every six months to detect external corrosion or damage to flasks or piping. There is currently no PMS requirement to accomplish this inspection; such a requirement should be developed.

3.3.3.2 Failure of Air Compressor Cooling Water Shut-Off Valves

The Worthington Class "S" oil-free compressor uses a Type D53X automatic cooling water shut-off valve manufactured by A.H. Cash Valve Manufacturing Corporation (APL 882241401). To date, the Fleet has reported few maintenance problems with this valve. However, during their long-term evaluation of the Class "S" air compressor, NSRDC noted that this valve operated erratically, even after it had been replaced with a new valve. This valve is of the same basic design as other valves installed on many Worthington air compressors (both high pressure and low pressure) and in each case studied to date, for either the FF-1052 Class or the DDG-37 Class, it has represented a problem. Therefore, its maintenance history should be monitored by the DDEOC Site Teams, to determine whether or not the latest modification to the basic valve has improved its reliability.

3.3.3.3 False Temperature Alarms on Air Dehydrators

The Commander, Philadelphia Naval Shipyard, has reported a problem with the installation of oil-free, low pressure (L.P.) air compressors with interlocked Type I (refrigeration) dehydrators. This installation uses the "lead-follow" compressor configuration. The "lead" compressor supplies normal L.P. air requirements. The "follow" compressor comes on the line automatically to assist the lead compressor during periods of high L.P. air demand.

False high-temperature indications are given on the Type I dehydrators when they are energized with no air supply from the interlocked air compressor. This situation occurs during periods of normal L.P. air demand (follow compressor standing by) and periods of low L.P. air demand (both lead and follow compressors standing by). The lack of air flow through the dehydrators and past the temperature sensors during these periods results in erroneous high-temperature indications and subsequent high-temperature alarms.

The problem of false temperature indication and alarm is a direct result of the compressor/dehydrator interlock modification, which requires the dehydrators to operate without an air supply for extended periods. The Philadelphia Naval Shipyard suggested as a possible permanent solution that the dehydrator evaporators be modified to permit placing the temperature sensor in the evaporator shell.

Philadelphia Naval Shipyard personnel have observed the false temperature indication and alarm condition on several ships, including the USS LUCE (DDG-38). With regard to the DDG-37 Class, the problem appears to be a result of the way the air compressors and the dehydrators were interlocked during the installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressors/Install Dryers). On all DDG-37 Class ships that have received ShipAlt DLG-6-1055K, the installations should be inspected for this

problem and the necessary corrections made. The following interim solution is recommended by the Philadelphia Naval Shipyard:

> "Modify alarm circuit on units now in service to prevent the dehydrator temperature alarm from sounding when its associated compressor is not running. This can be accomplished using the spare, normally open, contacts in the L.P. Air Compressor low oil pressure shutdown delay relay. These contacts should be wired in series with the existing temperature alarm delay contacts located in the dehydrator. If wired in this configuration, the alarm circuit would be enabled 15 seconds after the compressor starts. The 15-second delay should allow sufficient time for the refrigerated air in the evaporator to be blown past the existing temperature sensor. This is recommended only as an interim solution as it will not correct the inaccurate temperature indications. A nameplate warning personnel of temperature indicator inaccuracy when no air flow is present should be installed on each dehydrator."*

3.3.3.4 <u>Technical Manual Deficiencies</u>

During the ship visits, Ship's Force reported deficiencies in Technical Manual NAVSHIPS 0949-055-9010 for the Worthington 100 cfm oil-free low pressure air compressor. These deficiencies are known to the Navy, and the Air Compressor DART Program has undertaken to review and revise the manual, with an estimated completion date of 1 April 1980. Essentially, Fleet personnel believe that the existing manual is inadequate, specifically in the areas of system description and troubleshooting information.

3.4 HIGH PRESSURE AIR SYSTEM

The High Pressure Air System is supplied by two Worthington motor-driven high pressure air compressors, Class B/BB (4.5 cfh at 4500 psi discharge pressure). This air compressor is a reciprocating four-stage, vertical single acting, water-cooled type, with the first and third stages on one crank throw and the second and fourth stages on the opposite crank throw.

Mounted on the air compressor, and integral to its operation, is an automatic cooling water shutoff valve (APL 882240420) -- a normally closed diaphragm-operated valve that prevents cooling water from flowing through the compressor when the compressor is not operating.

The high pressure air compressors installed in the DDG-37 Class ships were originally manufactured in the early 1960s, but many have been extensively modified. The basic air compressor (APL 061900183) has been

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*False Temperature Indicators and Alarms on Modified Type I Low Pressure Air Dehydrators, Commander, Philadelphia Naval Shipyard, Ltr. Code 272 (DAO), 9252, 22 November 1977.

modified by using both ShipAlts and packaged modification kits from the Navy Supply System.

The first modification to the basic or original high pressure air compressor (APL 061900183) consisted primarily of installing new-design third- and fourth-stage pistons, cylinders, cylinder heads and valves, connecting rods with improved truck pins and bearings, a higher-speed cylinder lubricator, and more reliable lubricator check valves, as well as adding a third-stage condensate separator and a complete automatic separator drain system. When this modification was completed, the air compressor was assigned APL 061900266. The modification was accomplished under ShipAlt DLG-6-0116D (Improved Lubrication to High Pressure Air Compressor).

Fleet operational experience, as well as repair part usage data, as reported by MDS and as shown in Appendix B, Table B-1 (Significant Parts Usage), indicates that the modification of the high pressure air compressors that resulted in changing from APL 061900183 to APL 061900266 did not cause a noticeable improvement in the reliability of the air compressors and caused more oil carry-over into the air system piping because more oil was injected into the compression cylinders as a result of the installation of a high-rate cylinder lubricator. The problems experienced with the first compressor modification, together with advances in the development of "oil-free" air compressors, prompted the development of a second modification plan to use some of the ideas from the "new" oil-free air compressors and upgrade compressors identified by APL 061900183 and APL 061900266 to a "mini-lube" configuration (APL 061900338). The modification of the high pressure air compressors to a "mini-lube" configuration installed primarily new piston rings in the first and second stages, eliminated forced-feed lubrication to the first- and second-stage cylinders, replaced the fourth-stage piston assembly with a seal sleeve and follower assembly, and added more effective oil-flow sighting devices to the third- and fourth-stage cylinder lubricating lines. A packaged modification kit (Type II) assigned NSN 2S-4310-00-606-7288 was used at a cost of $11,570. When this modification was completed, air compressor APL 061900266 was designated APL 061900338.

Not all air compressors aboard DDG-37 Class ships underwent a two-step modification. Some of the basic air compressors (APL 061900183) were modified in one step, to a point where they were assigned APL 061900338. This change employed a Type I modification kit, NSN 2S-4310-00-596-6081, at a cost of $17,720.

Table A-1, Appendix A, presents the current modification status of this series of high pressure air compressors. Figure A-4, Appendix A, presents a sectional view of a Worthington Class B/BB air compressor.

3.4.1 Oil Carry-Over Into Air Piping

3.4.1.1 Background

The presence of oil in the air piping of the High Pressure Air System can be hazardous, explosion being one possible danger. Chapter 9490

(Compressed Air Plants) of the NAVSHIPS Technical Manual states that any amount of oil in the air piping system of more than a light film coating shall be removed by cleaning.

3.4.1.2 Discussion

DDG-37 Class ships are experiencing problems with oil in their high pressure air piping systems, as evidenced by review of the MDS narratives, discussions with NAVSEC and Fleet personnel, various modifications already made to the basic high pressure air compressor, and the existence of a ShipAlt to install an "oil-free" high pressure air compressor in the DDG-37 Class ships. As a further indication of this problem, two of the four SARPs reviewed by PERA(CRUDES) during the development of the DDG-37 Class Repair Profile showed that cleaning and flushing of the High Pressure Air System was required as an overhaul item.

Two factors contribute to the presence of oil in the High Pressure System piping: excess cylinder lubrication and dirty air line filters, as discussed in the following paragraphs.

Excess Cylinder Lubrication

Cylinder lubrication is provided by a four-feed Type PS-4 rotary drive unit with an internal gear train with a speed reduction ratio of either 200 to 1 (APL 650050003) or 85 to 1 (APL 650050005). These lubricators have one oil-delivery stroke for each 200 or 85 revolutions of the compressor crankshaft. Cylinder lubricator APL 650050005 is the higher-speed unit and is installed only on air compressors that have had ShipAlt DLG-6-0116D installed (which changed their APL to 061900266). From a review of the technical manuals and analysis of the problem, excess cylinder lubrication can be traced to the following:

1. Lack of detailed instructions in the technical manual and absence of any accurate way to measure cylinder oiling rate (APL 061900183)
2. The installed high-feed-rate cylinder lubricator (APL 061900266)
3. Improper adjustment of the oiling rate of the installed cylinder lubricator (APLs 061900183, 061900266, and 061900338)

In the case of item 1, it is recommended that the oil flow indicators currently installed for the third- and fourth-stage cylinders be replaced with the type currently installed on air compressor 061900338, i.e., NSN 1NM-6680-00-348-2658, costing $112 each. In addition to this change, operating personnel should be advised to reduce the first- and second-stage cylinder oiling rate to zero and allow these cylinders to be oiled by crankcase splash, as suggested in the equipment manual. Once the improved oil flow indicators are installed, the oiling flow rate for the third- and fourth-stage cylinder should be adjusted to a rate of between 5 and 10 drops per minute, depending on piston ring wear and carbon-deposit buildup on the suction and discharge valves. The simplest and most cost-effective approach to solving the problem caused by the high-feed-rate

cylinder lubricator (item 2 above) is to follow the same recommendations presented for item 1. The only difference is that the length of the lubricator pumping stroke of the pistons will have to be increased to provide for more lost vertical motion to reduce the oil flow resulting from each stroke.

Item 3 is an operator-related problem; increased training and attention to the operation of the air compressor should correct it.

Dirty High Pressure Air Line Filters

CUNO Model 1H1 air line filters are installed 3 to 5 feet downstream of each moisture separator in the High Pressure Air System piping. MRC R-12 (36-J76D-Y, Renew Element in High Pressure Air Line Filter) requires this PMS action every 200 hours of compressor operation. Fleet personnel report that this PMS action is not being performed because of the difficulty of opening the filter body to change the filter element.

MDS parts usage data also suggest that air line filter elements are not being replaced as often as PMS requires. If the filter elements had been replaced every 200 compressor operating hours, their average replacement interval would have been about every 11 months, causing 128 replacement elements to have been used, rather than the zero shown in MDS data. The 11-month estimate was derived as follows:

- The average monthly steaming hours under way and in port for DDG-37 Class ships is 360 hours (from ARINC Research Publication 1809-01-1-1546, *Effect of Overhaul on Ship Material Condition*, October 1976).
- The utilization rate of the High Pressure Air System is 10 percent during that interval, with at least one of the two compressors operating (from NAVSEC DDG-37 Class DDEOC Risk Analysis/Assessment Model).
- Combining these data mathematically yields

(360 Steaming Hours/Month) (0.05 Compressor Hours/Steaming Hour)

= 18 Compressors Hours/Month

and

$$\frac{\text{Filter Element Life}}{\text{Compressor Hours/Month}} = \frac{\text{200 Hours}}{\text{18 Hours/Month}} \simeq \text{11 Months Between Filter Element Replacement}$$

and

$$\frac{\text{Ship Operating Months}}{\text{Filter Replacement Interval (Months)}} = \frac{705}{11} \cong \text{64 Expected Filter Element Replacements During MDS Data Period for each filter (128 replacements for 2 filters)}$$

APLs 480060254, 480060293, 480060305, and 480060398 (CUNO Model 1H1 High Pressure Air Line Filters) allow two replacement filter elements as on-board spares. Since on-board spares are authorized, it is unlikely

that a significant number of filter elements would have been procured through channels outside the MDS reporting system. Because no elements have been reported as replaced throughout the data period, it is concluded that these filter elements are probably not being replaced as required by PMS on DDG-37 Class ships.

To resolve this problem, (1) emphasis should be placed on ensuring that this filter element is changed at the proper interval; (2) a ShipAlt should be developed to replace the current CUNO filter with a type requiring less effort to open in order to change filter elements; and (3) the periodicity of MRC R-12 (36-J76D-Y, Renew Element in High Pressure Air Line Filter) should be changed to annually or following 200 hours of operation, whichever occurs first.

3.4.1.3 Recommendations

The following near-term actions should be taken:

- Install oil flow indicators (NSN 1NM-6680-00-348-2658) on air compressors APL 061900183 and APL 061900266 (these indicators are a part of the "mini-lube" kit).
- Advise compressor operating personnel of the recommended cylinder oiling rates. (An article in the TYCOM's Fleet information bulletins could be used for this purpose.)
- Provide increased training in the area of compressor operation in general, and specifically in the operation of the cylinder lubricator, emphasizing the need for replacing air line filter elements.
- Change the periodicity of MRC R-12 (36-J76D-Y, Renew Element in High Pressure Air Line Filter) to annually or following 200 hours of operation, whichever occurs first.

For the long term, a ShipAlt should be developed to replace the current air line filter with a unit that requires less effort to open the filter body for changing filter elements.

3.4.2 Excessive Wear of Piston Rings and Seal Sleeves

3.4.2.1 Background

The piston rings and seal arrangements used on the Worthington high pressure air compressors can be any one of three types depending on which modification kit has been installed in the basic air compressor. The basic air compressor (APL 061900183) has a first-stage piston of the cast-aluminum alloy type fitted with two compression rings, one ventilated oil ring, and one oil scraper ring. In the second stage a cast-iron piston fitted with three compression rings, one ventilated oil ring, and one oil scraper ring is used. The third-stage piston, formed from a part of the first-stage piston, is fitted with six compression rings only. The fourth-stage piston is an assembly consisting of two end segments and an intervening series of spacers grooved at the outer diameter to accommodate twelve piston rings. All of the piston rings used on all four stages are of cast iron and are angle-cut.

If the basic air compressor has had ShipAlt DLG-6-0116D installed and APL 061900266 assigned, the high pressure air compressor employs three types of pistons to compress air in four stages. The first-stage piston is of the cast-aluminum alloy type, fitted with two compression rings and two ventilated oil rings. In the second stage, a cast-iron piston fitted with three compression rings and two ventilated oil rings is used. The third- and fourth-stage pistons are of the "built-up" type, consisting of alternate piston, spacer, and separator rings mounted on a piston rod. The third-stage piston has six compression rings, and the fourth-stage piston has seven piston rings. All of the piston rings used on all four stages are of cast iron and are angle-cut.

If the installed air compressor has been modified to the point where it has been assigned APL 061900338, the first- and third-stage pistons are made of a cast-aluminum alloy and combined into an integral assembly. The first-stage piston is fitted with four piston rings. In the top piston groove there is a wide bronze-filled teflon rider ring. In the next two piston grooves there are bronze-filled teflon seal rings that are grooved on their inner sides to hold a spring-steel expander band. In the bottom piston groove, below the trunkpin bore, there is a three-piece oil scraper ring. The second-stage piston is similar in construction to the first-stage piston except that it is smaller in diameter (it has a rider ring, two teflon seal rings, and a three-piece scraper ring). The third-stage piston is an assembly consisting of alternate separator rings, bronze spacer rings, and five bronze-filled teflon seal or compression rings (without steel expanders). The fourth-stage piston (see Figure A-5, Appendix A) does not have the conventional piston rings; the sealing element is a molded, fitted teflon sleeve. In service, air pressure exerted on its top face causes its formed lower end to flare over the sleeve follower and provide an air seal.

3.4.2.2 Discussion

Analysis of MDS data from all three high pressure air compressors (APLs 061900183, 061900266, and 061900338) reveals that much of the corrective maintenance and parts replacement associated with the high pressure air compressors consists of replacement of components of the piston assemblies (e.g., compression rings, ventilated oil rings, sleeves and sleeve followers, etc.). Table B-1 (Appendix B) provides data on significant parts usage for all three compressors. Discussions with NAVSEC, NSRDC, and Ship's Force personnel, and review of CASREP data indicate that piston ring and sleeve wear has been a problem.

The Worthington service manual for these high pressure air compressors states that after each 2,000 hours of compressor operation, piston rings and piston seals (sleeves) should be removed, inspected, and replaced if necessary. If the factor of 18 operating hours per month is used (as derived in Section 3.4.1.2), 2,000 operating hours would equate to approximately 111 ship operating months or 9.3 years. Table B-1 (Appendix B) shows that in almost all cases within the approximately 7.5 years of the MDS data period, the Parts Replacement Ratio (i.e., Parts Replaced/Total Part Population) is greater than 100 and in a few cases is greater than 200 for the piston rings installed in air compressors having APLs

061900183 and 061900266 and fourth-stage seals in air compressors having APL 061900338. This indicates that under current operating conditions, compressor piston rings and seals are not lasting the expected 2,000 hours but are being replaced, on the average, after approximately 45 months or 800 operating hours. Currently, PMS requires all inspections of piston rings and seals under MRC R-4 (27-L48E-N, Inspect Internal Parts) to be performed every 4,000 compressor operating hours. MRC R-4 should remain unchanged; however, on the basis of experience, two new PMS actions should be developed:

- Inspect the first-, second-, third-, and fourth-stage piston rings every 1000 hours of compressor operation or after 45 months of elapsed time, whichever occurs first (applicable to APLs 061900183 and 061900266 only). (This PMS action will require that Ship's Force be assisted by IMA personnel until an adequate shipboard maintenance capability has been developed.)
- Inspect the fourth-stage seal assembly every 1000 hours of compressor operation or after 45 months of elapsed time, whichever occurs first (applicable to APL 061900338 only).

The periodicity of 1000 hours was selected rather than 800 hours because it would be in better agreement with the timing of the other PMS actions for these air compressors; the 800-hour figure is only an approximation in any case. Even though the 800 operating hours between piston ring failures is an estimate, it does agree with the finding reported for the Worthington high pressure air compressors (APL 061900224) installed aboard the FF-1052 Class ships, which have piston rings that are the same as or similar to those installed in compressors APL 061900183 and APL 061900266. These PMS changes will not correct the problem of excessive piston ring wear but in the short term will help to prevent air compressor casualties by scheduling preventive maintenance actions closer to the experienced replacement intervals.

From the available MDS data, the major cause of the excessive piston ring wear was traced to inadequate cylinder lubrication caused by failed lubricator check valves. Although the specific reasons for the failure of these check valves were not addressed in the MDS data, it is estimated that the failures were caused by one or both of the following situations: (1) excessive cylinder lubrication -- carbon deposits from compression cylinders entering the check valve causing it to fail; and (2) inadequate cylinder lubrication -- products of normal wear joining with the minimal lubricant to form sludge, which then works its way into the check valve, causing valve failure. Valve failure in both cases is a result of a valve sticking open or having damaged or leaking seats. Failed cylinder lubricator check valves (NSN 1-HM-4820-00-783-5975) allow compressed air from the cylinders to force the cylinder lubricating oil back down the oil line, preventing it from reaching the cylinder and the piston ring. PMS currently has a maintenance action MRC R-6 (84-E45K-N: Clean and Inspect Cylinder Lubricator Check Valves) that is to be accomplished every 2000 hours of compressor operation. It is recommended that the periodicity of MRC R-6 be changed to every 1000 hours of compressor operation or 45 months, whichever occurs first, to coincide with MRC R-4 inspection of the piston rings.

The problem with the high failure rate of the fourth-stage sleeve and sleeve follower is that when the modification was made to install the teflon seal assembly in the fourth stage of the high pressure air compressor, in many cases the ship's high pressure air piping system was not equipped with a 2500-psi back-pressure valve, as recommended by the manufacturer. Without the back-pressure valve, not enough air pressure can be applied at compressor start-up to the teflon sleeve to enable it to seat properly and seal the fourth-stage cylinder. In most cases, the sleeve will seal between 600 psi and 1000 psi, but a 2500-psi valve setting is recommended by the manufacturer. To correct this problem, it is recommended that an automatic operating back-pressure valve set at 2500 psi be installed in the ship's air piping between the air compressor outlet and the ship's moisture separator flask. This back-pressure valve is available from either Worthington under their part number 7660B or from the Navy Supply System under ACN 2S-4310-LL-HAL-0148 (cost is $671). Because the sleeve and its follower are so critical to the operation of the compressor and because they have experienced a high usage rate, the allowance of on-board spares should be increased to 2 for each of these items.

As mentioned previously, inadequate cylinder lubrication will also cause excessive piston ring and sleeve wear. To provide the proper lubrication, cylinder lubricant flow rate should be maintained between 5 and 10 drops per minute; however, lack of attention by the operator to proper adjustment of the lubricator can lead to an inadequate flow rate. Since this is a human error rather than an equipment design problem, it should be correctable through increased operator training and alertness. To remind the operator that the cylinder lubricant flow rate is critical to proper operation of the air compressor, Engineering Operating Sequencing System (EOSS) procedures for the high pressure air compressor (HPAC/013) should be modified to include the additional step of checking the lubricant flow rate.

This problem occurs in the extreme, according to NAVSEC personnel, when operators allow the cylinder lubricator oil reservoir to run dry. To help overcome this problem, and minimize the amount of required operator attention to the compressor during shipboard operation, a ShipAlt should be developed to install an automatic compressor shutdown device, activated when the oil in the lubricator oil reservoir is low.

3.4.2.3 Recommendations

The following actions are recommended for the near term:

- Develop a PMS action to inspect the first-, second-, third-, and fourth-stage air compressor piston rings every 1000 hours of compressor operation or after 45 months of elapsed time, whichever occurs first (applicable to APLs 061900183 and 061900266 only).
- Develop a PMS action to inspect the fourth-stage seal assembly after every 1000 hours of compressor operation or after 45 months of elapsed time, whichever occurs first (applicable to APL 061900338 only).

- Change the periodicity of MRC R-6 (84-E45K-N: Clean and Inspect Cylinder Lubricator Check Valve) to accomplish every 1000 hours of compressor operation or every 45 months, whichever occurs first.
- Install an automatic operating back-pressure valve set at 2500 psi between the air compressor outlet and the ship's moisture separator flask (this valve is normally a part of the "mini-lube" kit).
- Make the following changes to shipboard parts allowance:

APL	NSN	Description	Unit Cost (Dollars)	Action
061900338	9C-4310-00-444-1747	Sleeve - 4 STG	279.76	Change allowance to 2
061900338	9C-4310-00-444-1748	Sleeve - FLWR	97.04	Change allowance to 2

- Provide increased operator training in the area of compressor operation in general, and specifically in the operation of the cylinder lubricator.
- Modify the EOSS procedures for the air compressor to add a step to check the cylinder lubricant flow rate (HPAC/013).
- Develop a ShipAlt to install an automatic shutdown device when the lubricator oil level reaches an unacceptably low level.

3.4.3 Leaks in Air Compressor Cooling Water System

3.4.3.1 Background

The cooling water system of the high pressure air compressor is supplied by water from the ship's salt water auxiliary cooling water system. Water flow through the compressor is controlled by an automatic shutoff valve (APL 882240420). This valve is an air-operated device that prevents the flow of water through the compressor during periods in which the compressor is shut down and ensures the restoration of water flow when the compressor starts. All compressor cooling elements (e.g., interstage coolers, cylinder jackets) are connected in series, with the last item being a manual water control or throttling valve to control the water flow rate through the compressor. All parts of the compressor cooling water system are constructed of corrosion-resistant material, and the system is protected against electrolytic corrosion by four zinc anodes.

3.4.3.2 Discussion

Review of MDS narrative data and discussions with Fleet personnel indicate that water leaks in the air compressor cooling water system represent a significant problem. Its severity was evident during the ship visits, during which two of the four high pressure air compressors inspected had failed shutoff valves and other water system leaks and the other two compressors were under repair by off-ship technicians.

Although leaks can appear in many places in the compressor water system, most have occurred in either the interstage cooler tube nests or in the water "jumper" piping. Navy sources (MDS data, Fleet personnel) attribute the leaks to two causes: failure of the automatic cooling water shutoff valve and corrosion of interstage cooler tubes. These are discussed in the following paragraphs.

Shutoff Valve Failure

The automatic cooling water shutoff valve controls water flow through the compressor cooling system. When the valve fails and remains fully or partially open, water can flow through the cooling system and erode the water jumper pipes. In addition, the water can erode the internal parts of the shutoff valve, allowing more water to flow.

MDS parts usage data do not reflect any significant usage of parts to repair the automatic shutoff valve. However, both FF-1052 and DDG-37 Fleet personnel and MDS narratives report significant problems with the valve. This apparent contradiction, as evidenced during the ship visits, can probably be attributed to the fact that Fleet personnel do not repair the valves when they fail, since they fail in the open position and do not have an immediate effect on the air compressor and since the throttling valve on the cooling water outlet side can be used to control water flow. Discussions with NSRDC personnel indicate that the problem with this valve may result partly from excessive friction between the poppet O-ring seals and the valve body, which causes the valve to stick open. This problem is known to both the Navy and the manufacturer. A modified shut-off valve, with teflon "slippers" added to the O-ring seals and some changes to the valve internals, is currently undergoing tests at NSRDC. If the test results indicate that the valve-sticking problem has been solved, all the cooling water shutoff valves should be modified in this same manner as they fail. An AER should be used as a means of control. Since the results of the test are unknown and because this valve represents a problem on both the DDG-37 and FF-1052 Classes, PMS action MRC R-11 (84-E45N-Y, Inspect Cooling Water Shutoff Valve) should be changed to read, "Accomplish after every 500 hours of operation or 30 months, whichever occurs first". This change incorporates the 30-month factor. On the basis of the 18 operating hours per month derived in Section 3.4.1.2, 500 hours is equivalent to approximately 30 months of valve operation.

In addition to changing the PMS action, the APL (882240420) for the shutoff valve should be modified to include an on-board spare allowance of four O-rings, enough to replace the four required in the two valves. There is currently no allowance for these O-rings on the APL.

Corrosion of Interstage Cooler Tubes

To help protect the interstage cooler tubes from corrosion, the air compressor has four zinc anodes. Analysis of MDS corrective-maintenance parts usage data and discussions with Fleet personnel indicate that the anodes are not being changed at all; they must be changed to protect the cooler tubes from electrolytic corrosion. Since anodes are readily machined from zinc bar stock, replacements may not be reported in the

MDS. The manufacturer recommends that when sea water is used as a cooling medium, zinc anodes be inspected and renewed after every 500 hours of operation.

There is no current PMS action requiring the inspection and renewal of these anodes. An MRC should therefore be developed to inspect and renew air compressor anodes every 500 hours of operation or 30 months, whichever occurs first. In addition to developing an MRC, an on-board allowance of eight anodes should be established to support the more frequent replacement of anodes expected with the introduction of the new MRC. The eight anodes would provide one full replacement set on board for the two compressors.

3.4.3.3 Recommendations

The following near-term actions should be taken:

- Monitor the tests at NSRDC to determine if the "modified" cooling water shutoff valve is an improvement over the existing valves. If it is a significant improvement, modify all the valves via AER as they fail.
- Change the periodicity of MRC R-11 (84-E45N-Y, Inspect Cooling Water Shutoff Valve) to every 500 hours of compressor operation or 30 months, whichever occurs first.
- Develop an MRC to inspect and renew, as necessary, the air compressor zinc anodes every 500 hours of compressor operation or 30 months, whichever occurs first.
- Make the following changes to shipboard parts allowances:

APL	NSN	Description	Unit Cost (Dollars)	Action
882240420	9Z-5330-00-187-3638	O-Ring	0.03	Change allowance to 4
061900183 061900266 061900338	9Z-5340-00-725-3998	Anode	0.29	Change allowance to 8

3.4.4 Excessive Third- and Fourth-Stage Air Valve Failures

3.4.4.1 Background

The third- and fourth-stage air suction and discharge valves on all three high pressure air compressors (APLs 061900183, 061900266, and 061900338) are similar in construction, the major difference being that the valves installed on air compressor APL 061900338 have a self-aligning or guided valve disk.

The third-stage cylinder head is provided with two suction and two discharge valves, and the fourth-stage head with one of each. The six

valves, spring-loaded dished-disk types, are identical and interchangeable. When used for discharge, the valve is installed with its seat toward the compression area of the head; for suction, the direction of the seat is reversed. Figure A-6 of Appendix A illustrates the suction and discharge valve assemblies installed on air compressor APL 061900338.

3.4.4.2 Discussion

MDS parts usage data (Appendix B, Table B-1), MDS narratives, and discussions with Fleet personnel show that the third- and fourth-stage air valves on air compressors APLs 061900183 and 061900266 require considerable maintenance and repair, much more frequently than the once every 2000 hours of compressor operation called for by PMS action MRC R-2 (27-L48D-N; Clean and Inspect Third and Fourth Stage Valve Assemblies). Depending on the particular air compressor, the manufacturer recommends cleaning and inspecting the third- and fourth-stage air valves either every 500 or 1000 hours of compressor operation. On the basis of Fleet maintenance experience with the failure of third- and fourth-stage valves and the manufacturer's recommendations, the periodicity of MRC R-2 (27-L48D-N) should be changed to 1000 hours of compressor operation or 45 calendar months, whichever occurs first. This periodicity will allow the inspection of suction and discharge valves concurrently with the inspection of the third- and fourth-stage piston rings (MRC recommended for development; see Section 3.4.2).

This recommendation does not apply to high pressure air compressor APL 061900338 because to date this compressor's air valves do not appear to present as severe a problem as those of the earlier models. This may be the result of several factors: (1) there is a smaller quantity of operating data on these air compressors, and the problem may not have had enough time to develop; (2) the air valves installed have the self-aligning or guided valve disks, which should reduce disk breakage problems; and (3) a smaller amount of cylinder lubricating oil is injected into the air system, with only two of the four compression cylinders lubricated by the cylinder lubricator.

More frequent inspection of the third- and fourth-stage valve assemblies as recommended above will not reduce the problem of excessive failures of the air valves, but for the short term it should help reduce the number of in-service failures by scheduling preventive maintenance actions closer to the failure interval. For the long term, self-aligning air valves should be installed in air compressors APL 061900183 and 061900266. From available information, it appears that this action can be accomplished by a simple valve replacement or by a minor modification to the third- and fourth-stage cylinder heads.

Failures of the third- and fourth-stage air valves can also result from the passage of foreign objects through a defective air filter, high air temperatures, excessive or inadequate cylinder lubrication, and excessive accumulation of carbon. Excessive carbon deposits is the cause given for most valve failures, but that condition normally results from a combination of excessive cylinder lubrication (see Section 3.4.1) and high air

temperature. Although no air temperature data are available, since compressor operating logs are not maintained (see Section 3.2), the presence of excessive carbon deposits and the known oil carry-over problem both indicate that abnormally high air temperatures are occurring in the third and fourth stages of the air compressor. The abnormally high temperatures range from normal operating levels (278°F in the third stage and 315°F in the fourth) to 430°F -- the automatic temperature-shutdown setting for the third- and fourth-stage air discharge monitors. When the compressor is operating with air discharge temperatures in this range, even for a short period, carbon deposits will rapidly form on the air valves, leading to valve disk breakage and undue wear on pistons, rings, liners, etc. The closer the air discharge temperature is to 430°F, the faster the carbon deposits will accumulate. The recommendations presented in Sections 3.2 and 3.4.1 for increased operator training in compressor operations and for reduced cylinder lubrication flow rate, as well as the recommendations concerning the need for air compressor operating logs, are also applicable to this problem.

3.4.4.3 Recommendations

For the near term, the following actions should be taken:

- Modify MRC R-2 (27-L48D-N, Clean and Inspect Third- and Fourth-Stage Valve Assemblies) for accomplishment after 1000 hours of compressor operation or 45 calendar months, whichever occurs first (APLs 061900183 and 061900266 only).
- Increase operator training in the area of compressor operation in general, and specifically in the operation of the cylinder lubricator (see Section 3.4.1).
- Develop, and provide to DDG-37 Class ships, air compressor operating logs containing definitive operating criteria (see Section 3.2).

For the long term, the third- and fourth-stage air suction and discharge valves should be replaced with self-aligning or guided air valves (APLs 061900183 and 061900266) (these valves are included in the "minilube" kit).

3.4.5 High Pressure Air System -- Minor Maintenance Problems

During the analysis of the High Pressure Air System, minor maintenance problems were identified in three areas: surface inspection of the system, shortage of air separator flasks, and lack of dehydrator technical manuals.

3.4.5.1 Surface Inspection of High Pressure Air System

Good engineering practice and Article 9490.151 of the NAVSHIPS Technical Manual require that all air flasks, separators, and piping be given a surface inspection every six months for external corrosion or damage to flasks or piping. There is currently no PMS action to accomplish this inspection, and it is recommended that such an action be developed.

3.4.5.2 Shortage of Air Separator Flasks

DDG-37 Class ships currently have high pressure air separator flasks that were manufactured to either MIL-C-15111 or 51-F-5. These designs are obsolete, according to Article 9490.174 of NSTM, and shall be replaced with flasks designed to MIL-F-22606 (NSN 1H-2090-00-148-1042). As of 4 January 1978, only four replacement flasks were in the supply system, and these were required to replace flasks that had failed certification under the old specifications. NAVSEA is aware of the problem, and steps are being taken to correct this critical shortage.

3.4.5.3 Lack of Dehydrator Technical Manual

Ship personnel on both ships visited reported that they did not have, and were unable to locate, a technical manual for the installed high pressure dehydrators (APL 440130022). These dehydrators (Model HPL-4500) were manufactured by Kahn and Company of Wethersfield, Connecticut, and are a commercial unit for which NAVSEA technical manuals were not developed. However, the manufacturer will provide commercial technical manuals if the serial numbers of the installed equipments are included in the request. These manuals will be provided either free or at a nominal charge.

3.5 SYSTEM MAINTENANCE REQUIREMENTS

3.5.1 System Maintenance Strategy

Analysis has shown that on the whole the components of the DDG-37 Class Compressed Air Systems are reliable and that the major portion of the maintenance burden is the result of a relatively few problems. It has also been determined that there is redundancy in the Compressed Air Systems and that an in-service failure of one of the equipments (i.e., air compressors) will not normally cause system failure. Since most Ship's Force personnel have not had any training to enable them to perform major items of corrective maintenance on these equipments, Class B overhaul of the system's air compressors should be accomplished at each ROH, with system condition assessment performed by site team personnel between equipment overhauls to identify necessary interim Class C repairs. When Compressed Air System operation and maintenance courses have been established and Fleet personnel have developed an adequate shipboard maintenance capability, the "hard time" requirement to accomplish a Class B Overhaul at each ROH can be eliminated. When this point has been reached, system overhaul requirements should be determined on the basis of performance testing.

3.5.2 Baseline Overhaul Requirements

The Baseline Overhaul concept of the DDEOC Program is to provide the maintenance necessary to restore a system to a condition in which, with a well engineered and executed maintenance program, it can be expected to perform satisfactorily over an extended operating cycle. In keeping with this policy, it will be necessary to perform Class B Overhaul on the installed low pressure air compressors, unless they are to be replaced

by oil-free units, and to perform Class B Overhaul on the installed high pressure air compressors. During their overhaul, the high pressure air compressors should also receive the "mini-lube" modification kit if it is not already installed. Specific Baseline Overhaul requirements resulting from this analysis, and other requirements from current Navy documentation such as the NAVSHIPS Technical Manual, are listed in Table 3-2.

3.5.3 Intra-Cycle Maintenance Requirements

There are no recommended "hard time" restorative Intra-Cycle Maintenance Requirements for components of the Compressed Air Systems. Upon completion of the Baseline Overhaul and the Compressed Air System repairs and modifications recommended as a result of this analysis, reliable system operation can be expected throughout the extended operating cycle. This prediction assumes the performance of currently specified PMS preventive maintenance actions, as modified in accordance with the recommendations herein. Also required are (1) the use of equipment operating logs for the early detection of correctable air compressor problems; and (2) additional personnel training and attention to detail, to develop an adequate shipboard air compressor operation, maintenance, and repair capability.

Until an adequate shipboard maintenance capability has been developed, Material Condition Assessment (MCA) procedures will have to be developed and utilized to determine those repairs necessary to maintain the Compressed Air Systems in an acceptable operating condition.

3.5.4 Follow-On Regular Overhaul Requirements

Future decisions to overhaul components of the Compressed Air Systems should be based on Material Condition Assessment checks and system performance testing rather than on a predetermined calendar basis. For test guidance, reference should be made to Shipboard Test Procedures 550TF030022 and 550TF010021 of NAVSEA 0941-LP-053-6080, 1200 PSI Propulsion Plant Test and Certification Manual.

Until an adequate shipboard maintenance capability has been developed, provisions should be made to accomplish the following maintenance actions during follow-on overhauls:

- Ship Service (Low Pressure) Air System
  - Perform Class B Overhaul on 4 oil-free compressors
  - Perform Class C repairs on 4 Type I (Refrigeration) air dehydrators
  - Perform Class C repairs on 2 Type III (Refrigeration/Desiccant) air dehydrators or 2 Type II (Desiccant) air dehydrators
  - Clean and test low pressure air receivers
  - Test and clean, as necessary, low pressure air piping system, including repair of leaking valves

Table 3-2. BASELINE OVERHAUL REQUIREMENTS

Component	Recommendation
Ship Service (Low Pressure) Air System	
A. Repairs and Overhauls	
1. Low Pressure Air Compressors	Perform Class B Overhaul of 4 Worthington oil-free air compressors.
2. Low Pressure Air Dehydrators (Type III)	Perform Class B overhaul of 2 Howell Laboratories dehydrators -- overhaul to include replacement of ball check valves if units are not replaced by ShipAlt.
3. Low Pressure Air Dehydrators (Type I)	Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/Install Dryers) to determine if false temperature indication and alarm problem exists; make necessary corrections.*
4. Low Pressure Air Flasks	Remove, clean, test, preserve, and reinstall low pressure accumulator air flasks.
5. Air System Piping	Inspect air system piping for oil contamination and for external corrosion or damage; make necessary repairs and test.*
B. Alterations	
1. Low Pressure Air Compressors	Accomplish ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/ Install Dryers) if not already completed.
2. Low Pressure Air Dehydrators (Type III)	Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kits) if units are not replaced. Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryers with Type II) as applicable.
High Pressure Air System	
A. Repairs and Overhauls	
1. High Pressure Air Compressor	Perform Class B Overhaul of 2 Worthington air compressors -- overhaul to include installation of "mini-lube" modification kits as applicable.* Install automatic operating back-pressure valve in the air piping system between the compressor and the moisture separator, if not already installed (APL 061900338 only).* Provide recommended on-board spares during SOAP, if not previously accomplished.
2. High Pressure Air Dehydrators (Type II)	Perform Class B Overhaul of 2 installed air dehydrators.
3. High Pressure Air Flasks	Remove, clean, inspect, and reinstall high pressure air flasks. (Depending on dates of last inspection, this could include up to 5 flasks.
4. High Pressure Air Separator Flasks	Remove, clean, and inspect 2 air separator flasks; replace those that are obsolete (see NSTM Article 9490.174).
5. Air System Piping	Inspect air system piping for oil contamination and for external corrosion or damage; make necessary repairs and test.*
B. Alterations	
1. High Pressure Air Compressors	Accomplish ShipAlt DLG-6-0184K (Install Elapsed Time Meter and Events Indicator on H.P.A.C.) if not already completed. Accomplish lubrication low-oil-level shutdown device ShipAlt when this ShipAlt is developed.**
2. Air Line Filters	Accomplish air line filter replacement ShipAlt, when this ShipAlt is developed.**

*These maintenance actions are not included in the DDG-37 Class SARP Planning Document (February 1978).
**These maintenance actions should be included in the DDG-37 Class SARP Planning Document when the ShipAlt or replacement unit has been developed.

* High Pressure Air System
  * Perform Class B Overhaul on 2 air compressors
  * Perform Class C repairs on 2 Type II (Desiccant) air dehydrators
  * Clean and test high pressure air flasks and separators
  * Test and clean, as necessary, high pressure air piping system, including repair of leaking valves

3.6 REQUIREMENT FOR OIL-FREE HIGH PRESSURE AIR COMPRESSOR

As discussed in Section 3.1, the Navy is developing ShipAlt DDG-37-1206K (Replace High Pressure Air Compressor) to replace the current oil-lubricated air compressor with an oil-free type. The primary reason for switching air compressors is to resolve the problem of oil carry-over into air system piping. However, that problem can be resolved, or at least significantly reduced, without replacing the oil-lubricated air compressors. The decision to replace the existing high pressure air compressors with oil-free types should be reviewed for possible reversal in light of the comments provided thus far in this analysis, as supplemented by the following points:

* The estimated cost to replace the 20 existing high pressure air compressors is approximately $4 million ($2.8 million for new oil-free air compressors at $140,000 each, and $1.2 million for installation at $60,000 each). The $140,000 item cost is a NAVSEC estimate; the $60,000 installation charge was developed from shipyard costs to install similar equipments. The $4 million is, of course, a rough estimate, but it does indicate that the Navy would realize considerable savings by not replacing the existing oil-lubricated air compressor.
* The estimated cost to install "mini-lube" kits on high pressure air compressors that do not have the modification is $181,160 ($88,600 for 5 Type I modification kits at $17,720 each, $92,560 for 8 Type II modification kits at $11,570 each). Since these kits can be installed during a Class B Overhaul of the air compressors, the total cost to upgrade all of the air compressors to the "mini-lube" modification and to perform Class B Overhaul on them would be approximately $800,000 ($181,160 for the kits and $623,000 to overhaul 20 high pressure air compressors (the overhaul costs were developed from authorized DDG-37 Class SARPs).
* Discussions with NAVSEC, Naval Weapons Support Center, Crane, Indiana (the In-Service Engineering Activity for oil-free air compressors), and NSRDC concerning oil-free high pressure air compressors indicate that the proposed replacement air compressor is not trouble-free. For example, two major problems already identified are related to excessive piston ring wear and problems with the condensate drain system. In other words, the Navy could be faced with the possibility of trading one set of problems (those associated with the oil-lubricated compressors) for another (those associated with oil-free air compressors).

- The oil-free air compressor is at least as complex as the oil lubricated type.
- If the Ingersoll-Rand oil-free air compressor is used as a replacement, as is expected, the space for the air compressor itself and for servicing may be inadequate, since the IR compressor is at least 50 percent larger than the installed Worthingtons.
- The introduction of new equipment into the Fleet is usually accompanied by supply support problems. These problems appear to have been overcome for the present air compressors.
- Training in the operation, maintenance, and repair of both air compressors is or will be required.
- If the present oil-lubricated air compressor is retained, there is an opportunity to develop, in the near term, an adequate shipboard maintenance capability that will be retained in the future and not have to be redeveloped with the introduction of oil-free high pressure air compressors.
- While an oil-free air compressor will reduce the risk of explosion in the High Pressure Air System, the occurrence of these explosions today is rare. Even though the use of an oil-lubricated air compressor includes a risk of explosion, implementation of the recommendations of this report will reduce that risk even further.
- A "mini-lube" modification kit evaluation, conducted in 1975 by NSRDC, concluded, as a result of 5621 hours of compressor operation, that

  "The mini-lube conversion is recommended as a viable means of significantly improving the service of older Worthington compressors where it is not economically feasible to install new oil-free machinery."*

It appears from this analysis that the requirement to replace these units with an oil-free type could be eliminated with an investment in 13 "mini-lube" modification kits and personnel training in the operation, maintenance, and repair of oil-lubricated high pressure air compressors.

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*Richard L. Helmick, "Evaluation of the Worthington Class B/BB Mini-Lube Modification Kit", NSRDC Evaluation Report PAS-74-63 (February 1975).

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the conclusions and recommendations resulting from the Review of Experience of the Compressed Air Systems of DDG-37 Class ships.

4.1 CONCLUSIONS

Significant conclusions resulting from this ROE are as follows:

- Major repairs of the Compressed Air Systems will be required during Baseline Overhaul.
- Personnel training in the operation, maintenance, and repair of the systems is inadequate; however, the DART Air Compressor Improvement Program is moving towards correcting this deficiency.
- Class B Overhaul of system components will be required at each ROH, with Material Condition Assessment (MCA) performed between overhauls to identify necessary Class C repairs, until an adequate shipboard maintenance capability is developed.
- The systems are adequately supported by the Navy Supply System.
- Most system problems or parts replacements are either nonrecurring maintenance items, consumable items (packing, gaskets, etc.), or routine upkeep.
- Most compressor problems can be traced to excessive or inadequate cylinder lubrication, water leaks, or the need for additional or revised PMS actions (e.g., review zinc anodes, inspect piston rings, inspect air suction and discharge valves, etc.).
- In many cases, there is no positive means for scheduling PMS actions that are based on compressor operating hours alone, since operating logs are not maintained nor are elapsed-time meters installed on all air compressors.
- Even though the Worthington oil-free low pressure air compressor has experienced about twice the maintenance burden per operating year of the air compressor it replaces, most of the problems reported to date do not appear to be Class-wide.

- After the air compressors, the weak links in the Compressed Air Systems are the dehydrators, particularly those supplying the Electronics Dry Air System.
- The "mini-lube" modification kit can significantly improve the service of older Worthington high pressure air compressors.
- The decision to replace the present oil-lubricated high pressure air compressors with an oil-free type should be reconsidered in light of this analysis.

4.2 RECOMMENDATIONS

Corrective actions and improvements required for the Compressed Air Systems are grouped as follows:

- Baseline Overhaul (BOH) Requirements
- Intra-Cycle Maintenance Requirements
- Follow-On ROH Requirements
- Reliability and Maintainability Improvements
- Planned Maintenance System (PMS) Changes
- Industrial Facility Improvements
- IMA Improvements
- Integrated Logistic Support (ILS) Improvements

Table 4-1 summarizes all recommendations resulting from the Review of Experience. Appendix D contains a description and installation status of the Compressed Air Systems' ShipAlts that are applicable to the DDG-37 Class. A detailed listing of recommended PMS changes is included in the DDEOC MRC Evaluation Table of Appendix E. Action items resulting from the recommendations of this report are listed in the DDEOC Action Table of Appendix F.

Table 4-1. SUMMARY OF ROE RECOMMENDATIONS

Component	Recommendation
Baseline Overhaul Requirements	
A. Repairs and Overhauls	
Low Pressure Air Compressors	Perform Class B Overhaul of 4 Worthington oil-free compressors.
Low Pressure Air Dehydrators (Type III)	Perform Class B overhaul of 2 Howell Laboratories dehydrators; overhaul to include replacement of ball check valves, if dehydrators are not replaced by ShipAlts.
Low Pressure Air Dehydrators (Type I)	Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressors/ Install Dryers) to determine if false temperature indication and alarm problem exists; make necessary corrections.
Low Pressure Air Flasks	Remove, clean, test, preserve, and reinstall low pressure accumulator air flasks.
High Pressure Air Compressors	Perform Class B Overhaul of 2 Worthington air compressors; overhaul to include installation of "mini-lube" modification kit, as applicable.
	Install an automatic operating back-pressure valve in the air piping system between the air compressor and the moisture separator if not already installed (APL 061900338 only).
	Provide recommended on-board spares during SOAP, if not previously provided.
High Pressure Air Dehydrators (Type II)	Perform Class B Overhaul of 2 installed air dehydrators.
High Pressure Air Flasks	Remove, clean, inspect, and reinstall high pressure air flasks. (Depending on the dates of the last inspection, this could include up to 5 flasks.)
High Pressure Air Separator Flasks	Remove, clean, inspect 2 air separator flasks; replace those which are obsolete.
Air System Piping (L.P. and H.P.)	Inspect air system piping for oil contamination and for external corrosion or damage; make necessary repairs and test.
B. Alterations	
Low Pressure Air Compressor	Accomplish ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/Install Dryers) if not already completed.
Low Pressure Air Dehydrators (Type III)	Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit) if dehydrators are not replaced.
	Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryers with Type II) as applicable.
High Pressure Air Compressors	Accomplish ShipAlt DLG-6-0184K (Install Elapsed Time Meter and Events Indicator on H.P.A.C.) if not already completed.
	Accomplish lubricator low-oil-level shutdown device ShipAlt when it is developed.
Air Line Filters	Accomplish air-line filter replacement ShipAlt when it is developed.
Intracycle Maintenance Requirements	
All Equipments of the Compressed Air Systems	Accomplish existing PMS requirements as modified by recommendations of this report. Accomplish MCA procedures to identify necessary Class C repairs.
Follow-On ROH Requirements	
Low Pressure Air Compressors	Perform Class B Overhaul of 4 Worthington oil-free air compressors.
Low Pressure Air Dehydrators (Type I)	Perform Class C repairs to 4 Type I air dehydrators.
Low Pressure Air Dehydrators	Perform Class C repairs to 2 Type II or 2 Type III air dehydrators.
High Pressure Air Compressors	Perform Class B Overhaul of 2 high pressure air compressors.
High Pressure Air Dehydrators (Type II)	Perform Class C repairs of 2 Type II air dehydrators.
Air System Flask and Separators	Remove, clean, test, preserve, and reinstall air system flasks and separators.
Air System Piping	Inspect air system piping for oil contamination and for external corrosion or damage, including leaking valves; make necessary repairs and test.
Reliability and Maintainability Improvements	
Low and High Pressure Air Compressors	Develop standard operating logs and provide to ships.
	Install elapsed-time meters and events indicators.
Low Pressure Air Dehydrators (Type III) (if not replaced by ShipAlt)	Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit).
	Replace the Polyethylene Ball Check Valves (via AER).
	Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryer with Type II) as applicable.
	Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressors/ Install Dryers) to determine if false temperature indication and alarm exists.
High Pressure Air Compressors	Install "mini-lube" modification kit. Install automatic operating back-pressure valve.
	Develop ShipAlt to install an automatic compressor shutdown device controlled by the oil level in the cylinder lubricator oil reservoir.
Air Line Filter	Develop ShipAlt to replace current air-line filter with unit that requires less effort to change filter elements.

(continued)

Table 4-1. (continued)

Component	Recommendation
Planned Maintenance System (PMS) Changes	
High Pressure Air Compressor	Develop a PMS action to clean and inspect the 1st, 2nd, 3rd, and 4th stage air compressor piston rings every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier (APLs 061900183 and 061900266 only).
	Develop a PMS action to inspect the 4th stage seal assembly after every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier (APL 061900338 only).
	Change the periodicity of MRC R-6 (84-E45K-N, Clean and Inspect Cylinder Lubrication Check Valves) to every 1000 hours of compressor operation or every 45 calendar months, whichever occurs earlier.
	Change the periodicity of MRC R-2 (27-L48D-N, Clean and Inspect 3rd and 4th Stage Valve Assemblies) to every 1000 hours of compressor operation or 45 calendar months, whichever occurs earlier (APLs 061900183 and 061900266 only).
	Develop a PMS action to inspect and renew, as necessary, the air compressor zinc anodes every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.
Cooling Water Shut-Off Valve	Change the periodicity of MRC R-11 (84-E45N-Y, Inspect Cooling Water Shut-Off Valve) to every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.
Air Line Filter	Change periodicity of MRC R-12 (36-J76D-Y, Renew Element in High Pressure Air Line Filter) annually or after 200 hours of operation, whichever occurs earlier.
Air System	Develop a PMS action to inspect air system for corrosion or damage every 6 months.
Industrial Facility Improvements	
None	
IMA Improvements	
None	
Integrated Logistic Support (ILS) Improvements	
Low and High Pressure Air Compressors	Provide increased operator training at the shipboard level.
	Establish air compressor maintenance courses at the Fleet Training Center level.
	Place additional emphasis on compressed air system operation at MM and BT "A" School.
Low Pressure Air Compressor	Ensure that information on the proper replacement air intake filter element is known at the ship level.
	Revise the technical manual for the Worthington Oil-Free Air Compressors (NAVSHIPS 0949-055-9010) to include more information on system details and equipment troubleshooting.
Low Pressure Air Dehydrators (Type III)	Either update the NAVSHIPS *Technical News* article "Modifying and Operating Dehydrators" and republish it in the *NAVSEA Journal* or condense it and release it to the Fleet as a Naval message.
High Pressure Air Compressor	Revise APL 061900338 to provide additional parts support and increased support depth (i.e., 4th stage sleeves and sleeve followers and zinc anodes).
	Modify the EOSS procedures for the high pressure air compressor to add a step to check the cylinder lubricant's flow rate (HPAC/013).
	Advise compressor operating personnel of the recommended cylinder oiling rates.
	Revise APL 882240420 to increase the on-board allowance of O-rings.
	Revise APLs 061900183 and 061900266 to add an allowance of zinc anodes.
High Pressure Air Dehydrators	Provide ships of the Class having Kahn and Company high pressure air dehydrators (APL 440130022) with technical manuals for these units.
High Pressure Air Separator Flasks	Increase the availability of replacement high pressure air separator flasks that meet MIL-F-22606.
Cooling Water Shut-Off Valve	Monitor the operation of the most recent design of this valve (D53X) to determine if the latest changes have improved the valve's performance.
	Monitor the tests at NSRDC to determine if the "modified" cooling water shut-off valve is an improvement over the existing valves. If the valve is a significant improvement, modify all valves via AER as they fail.
Air System	Develop Material Condition Assessment (MCA) procedures for the Compressed Air Systems.

SOURCES OF INFORMATION

The specific sources of information used as the basis for the System Maintenance Analysis of the Compressed Air Systems are listed below.

1. Trip Report (13-16 March 1978); ARINC Research visit to COMNAVSURFLANT Staff (Code N4441), DDG-42, and DDG-44.

2. Trip Report (7 April 1978); ARINC Research visit to Naval Ship Research and Development Center (Annapolis), (Code 2745).

3. Trip Report (2 May 1978); ARINC Research visit to NAVSEC, Washington, Code (6153B).

4. Generation IV MDS part and maintenance data for DDG-37 Class, covering the period 1 January 1970 through 30 September 1977.

5. CASREPs for DDG-37 Class, 1 July 1973 through 30 September 1977.

6. NAVSHIPS 0901-LP-490-0003, Technical Manual, Chapter 9490, "Compressed Air Plants".

7. OPNAVINST 4790.4, Material Maintenance Management (3M) Manual, Volumes I, II and III: dated June 1973.

8. Maintenance Index Pages (MIPs) for the Compressed Air Systems A-3/55-27, A-702/2-A6, A705/14-85, A700/1-46.

9. Maintenance Requirement Cards (MRCs) as listed on the Compressed Air Systems MIPs (various dates).

10. NAVSHIPS SIB DLG9-2, N.S. 0905-475-4020, Piping Ventilating, Heating and Air Conditioning Systems, Volume 2, March 1972.

11. Type Commander's COSAL, SURFLANT (dated 28 February 1977) and SURFPAC (dated 21 August 1977).

12. PERA (CRUDES) Index of Cruiser/Destroyer Technical Repair Standards (TRS) and Repair Material Requirements Lists (MRL) (dated March 1978).

13. NAVSEA 0941-LP-053-6080, 1200 PSI Propulsion Plant Test and Certification Manual; Appendix A-7, DDG-37 Class.

14. Engineering Operational Sequencing System (EOSS), Engineering Operational Procedures (EOP) for Compressed Air Systems.

15. SMMSO Maintenance Benefit Recommendation #12-75, "High Pressure Air Compressor Overhaul Interval Extension". Commander, Naval Ship Engineering Center ltr. 6107 E2B/RJM Ser. 524 of 10 September 1975 w/encl.

16. PERA(CRUDES), "DDG-37 Repair Profile" dated June 1977.

17. PERA(CRUDES), "Baseline SARP for Baseline Overhaul (BOH) of DDG-37 Class Ships".

18. Ship Alteration Records

19. Ship Alteration Information Manual, DDG-37 Class prepared by PERA (CRUDES), dated 1 November 1976.

20. DDEOC Repair Requirements for BOH (DDG-37 Class), dated February 1977.

21. NAVSHIPS 0949-055-9010, Equipment Manual for Class S 100 CFM 125 psi Low Pressure Air Compressor.

22. NAVSHIPS 0949-037-0010, Service Manual High Pressure Class B/BB Air Compressor.

23. NAVSHIPS 349-0570, Technical Manual for 50 CFM, 100 psi Class CC Low Pressure Air Compressor.

24. NAVSHIPS 0949-036-6010, Equipment Manual for Dehydrator, Low Pressure Air, for Special Applications, Type III (Refrigeration-Desiccant), Class 2 (30 SCFM).

25. DART Air Compressor Improvement Program Quarterly Report, Commander, Naval Sea Systems Command, Ltr. 0492D/AEK, 4790.124, Ser. 157 of 12 December 1977.

26. Authorized SARPs for the follow DDG-37 Class ships:

USS COONTZ (DDG-40) dated 31 January 1977
USS FARRAGUT (DDG-37) dated 30 August 1977
USS DAHLGREN (DDG-43) dated February 1978
USS LUCE (DDG-38) undated

27. DART Air Compressor Improvement Program Draft Navy Training Plan, (D) NTP-S-60-7501, Commander, Naval Sea Systems Command, Ltr., 047/WBR, Ser. 36 of 29 May 1975.

28. NAVSEA 0905-LP-513-0010, Operating Guide for Propulsion Machinery (USS DEWEY DDG-45), dated April 1976.

29. NAVSEA 0905-504-1010, Operating Guide for Propulsion Machinery (USS MAHAN DDG-42), dated April 1976.

30. COMNAVSURFLANT Alteration Management Summary, dated 22 February 1978.

31. ARINC Research Corporation, Effects of Overhaul on Ships Material Condition, publication 1808-01-1-1546, October 1976.

32. NAVSEC DDG-37 (FARRAGUT) Class DDEOC Risk Analysis/Assessment Model, Report No. 6112-032-77, 29 April 1977.

33. ARINC Research Corporation, System Maintenance Analysis, FF-1052 Class High Pressure Air System, publication 1646-03-16-1630, July 1977.

34. COMNAVSEASYSCOM Message R131939Z Jan 78; Subj: HP Air Separator Flasks.

35. Helmuth, Richard L., "Evaluation of the Worthington Class B/BB Minilube Modification Kit", Naval Ship Research and Development Center, Report PAS-74-63, dated February 1975.

36. Braden, J.R. and Giannini, R.M., "Long-Term Evaluation of Worthington Class S, 100 SCFM, 125 PSIG Oil-Free Air Compressor Package", David W. Taylor Naval Ship Research and Development Center, Report PAS-76-20, dated September 1976.

37. Progress on the Long-term Evaluation of a Worthington Class S, SCFM, 125 PSIG Oil-Free Air Compressor; Report of: Commander, David W. Taylor Naval Ship R&D Center, Ltr. 2745: JRB, 9551, TM-27-76-89, dated 20 October 1976.

38. Long-term Evaluation of a Worthington Class S, 100 SCFM, 125 PSIG, Oil-Free Air Compressor; Commander, David W. Taylor Naval Ship R&D Center, Ltr. 2745:JRB, 9551, TM-27-77-84, dated 24 Jan. 1978.

39. False Temperature Indicators and Alarms on Modified Type I Low Pressure Air Dehydrators; Commander, Philadelphia Naval Shipyard, Ltr. Code 272 (DAO), 9252, dated 22 Nov. 1977.

40. ARINC Research Corporation, DDG-37 Class SARP Planning Document, Publication 1809-01-2-1711, February 1978.

41. Jones, R. and Goodhue, J., "Modifying and Operating Dehydrators", NavShips Technical News, August 1972, pp. 20-23.

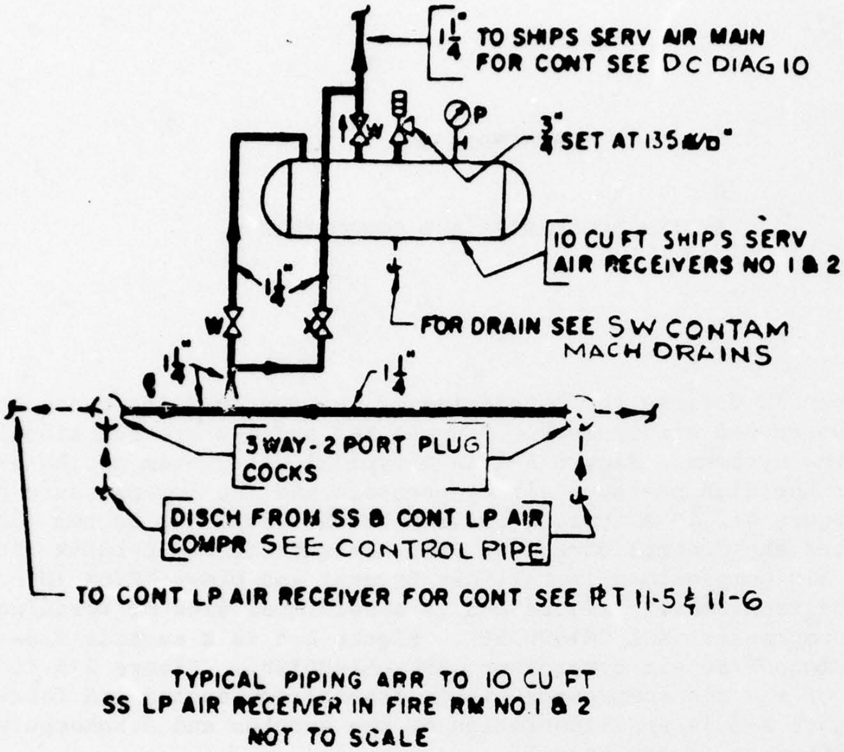
42. Letter to Commander, Naval Sea Systems Command (PMS-306) from Officer in Charge, Naval Ship Engineering Center (Philadelphia Division), Subj: "Performance Test Analysis for High Pressure Air Compressors; Final Report of"; Ltr 6731: AAM: cp; 9551, FT-3854, Ser 87 of 10 May 1976.

APPENDIX A

SYSTEM BOUNDARIES AND COMPONENTS

This appendix defines the boundaries of the System Maintenance Analysis of the Compressed Air Systems. Figures A-1 and A-2 are functional diagrams of the systems. Figure A-1 is a typical air system piping arrangement for the high pressure air compressors and the low pressure air receiver. Figure A-2 is a typical diagram of the Vital Air System (low pressure) after the accomplishment of Ship Alterations DLG-6-1055K (Replace Low Pressure Air Compressors/Install Air Dryers) and DLG-6-1098K (Electronic Dry Air Modifications). Figure A-3 is a sectional view of Worthington Class S air compressor (APL 061900359). Figure A-4 is a section view of Worthington Class B/BB air compressor (APL 061900338). Figure A-5 is an illustration of the air compressor piston assemblies (second and fourth stages). Figure A-6 is an illustration of the suction and discharge valve assemblies (third or fourth stage).

Table A-1 shows equipment configuration of the Compressed Air Systems in DDG-37 Class ships, as derived from the Type Commander COSAL for the Class. In the development of this table, an attempt was made to resolve inconsistencies among Type Commander's COSAL and MDS data. However, all such inconsistencies could not be resolved. This configuration is the best estimate from all available data sources. The table does not include APLs or population data for multi-use valves or minor valving of the system, since those components were not significant to the Review of Experience.



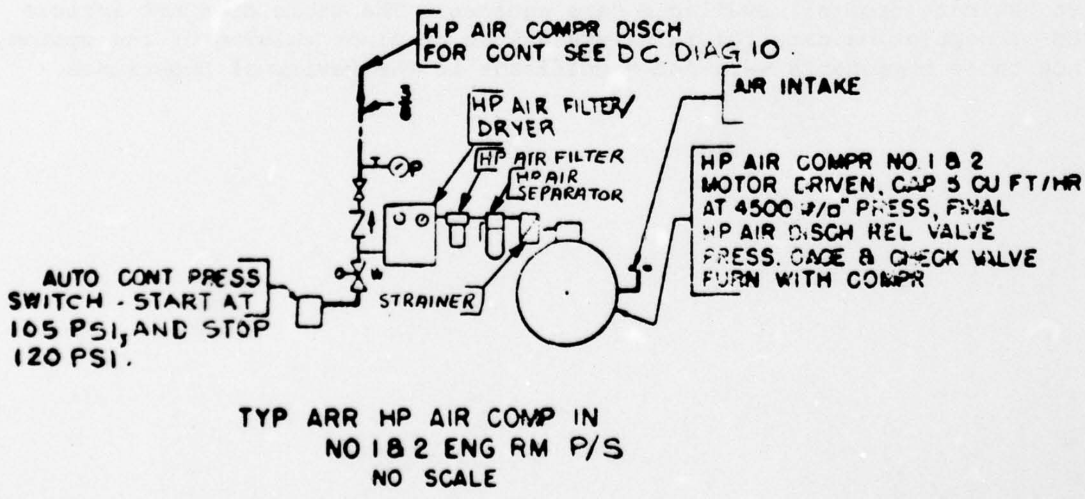


Figure A-1. TYPICAL AIR SYSTEM PIPING ARRANGEMENTS

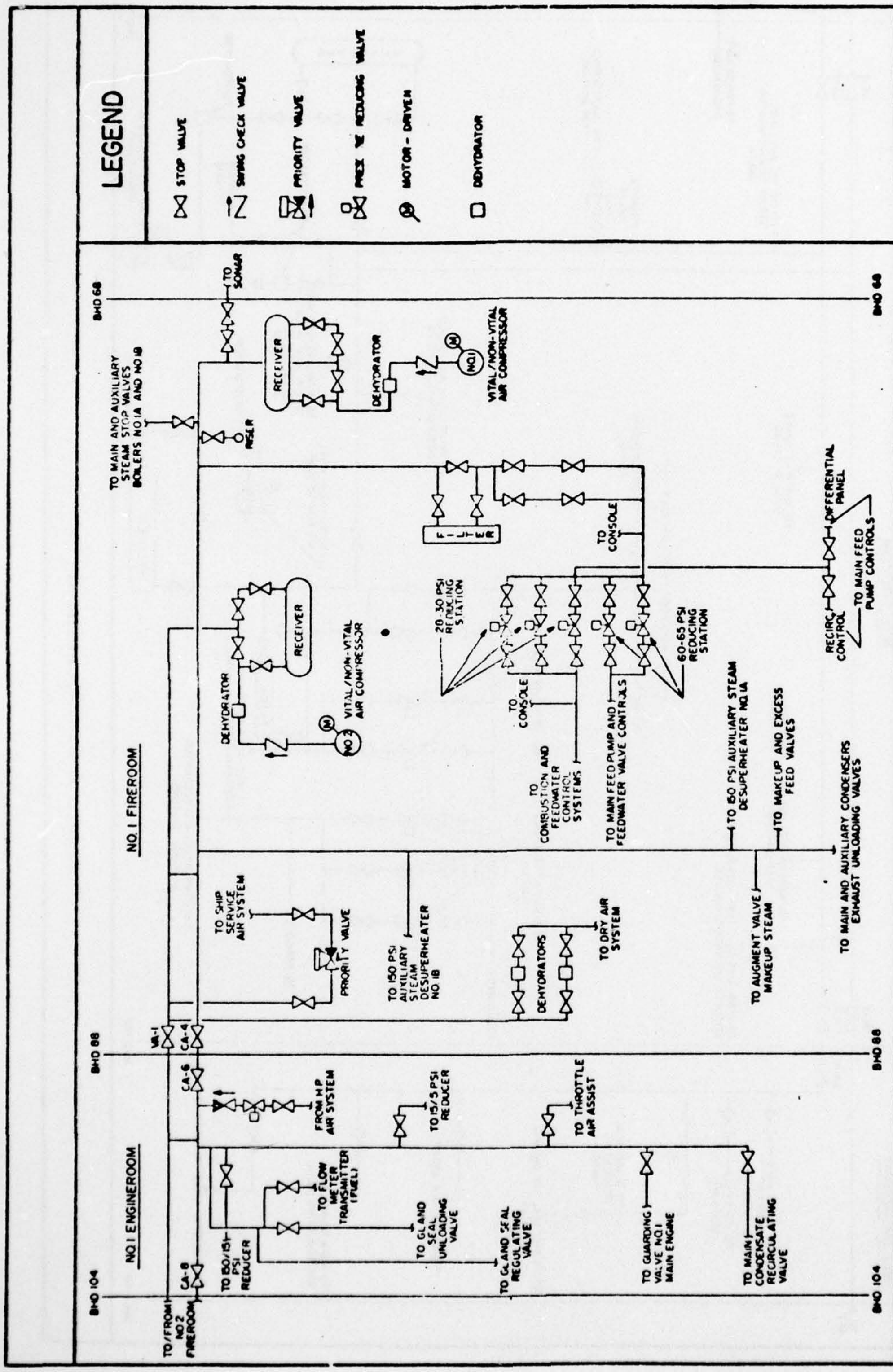


Figure A-2. DIAGRAM FOR VITAL AIR SYSTEM (continued)

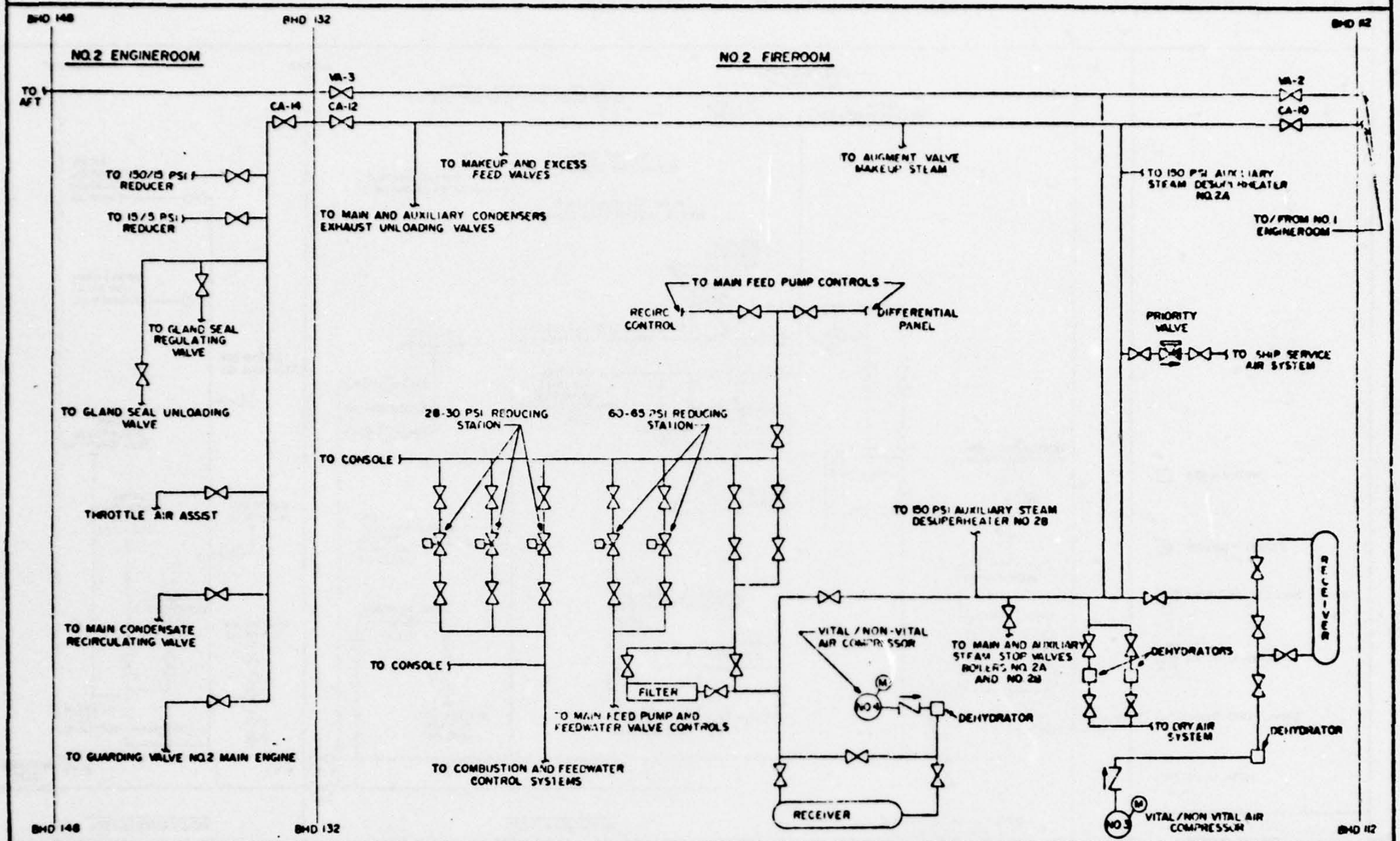


Figure A-2. (continued)

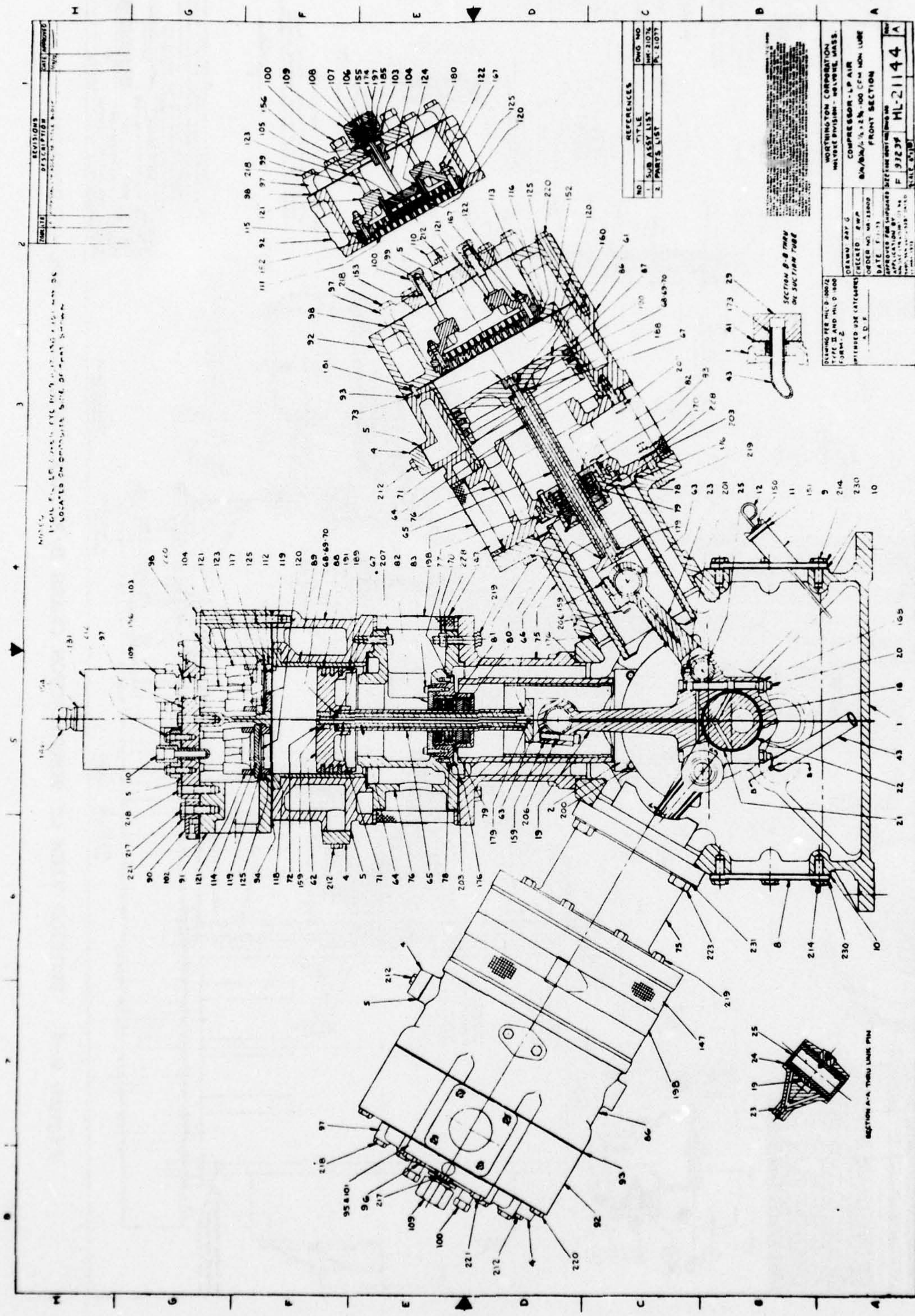


Figure A-3. SECTION VIEW OF WORTHINGTON CLASS S AIR COMPRESSOR (APL 061900359)

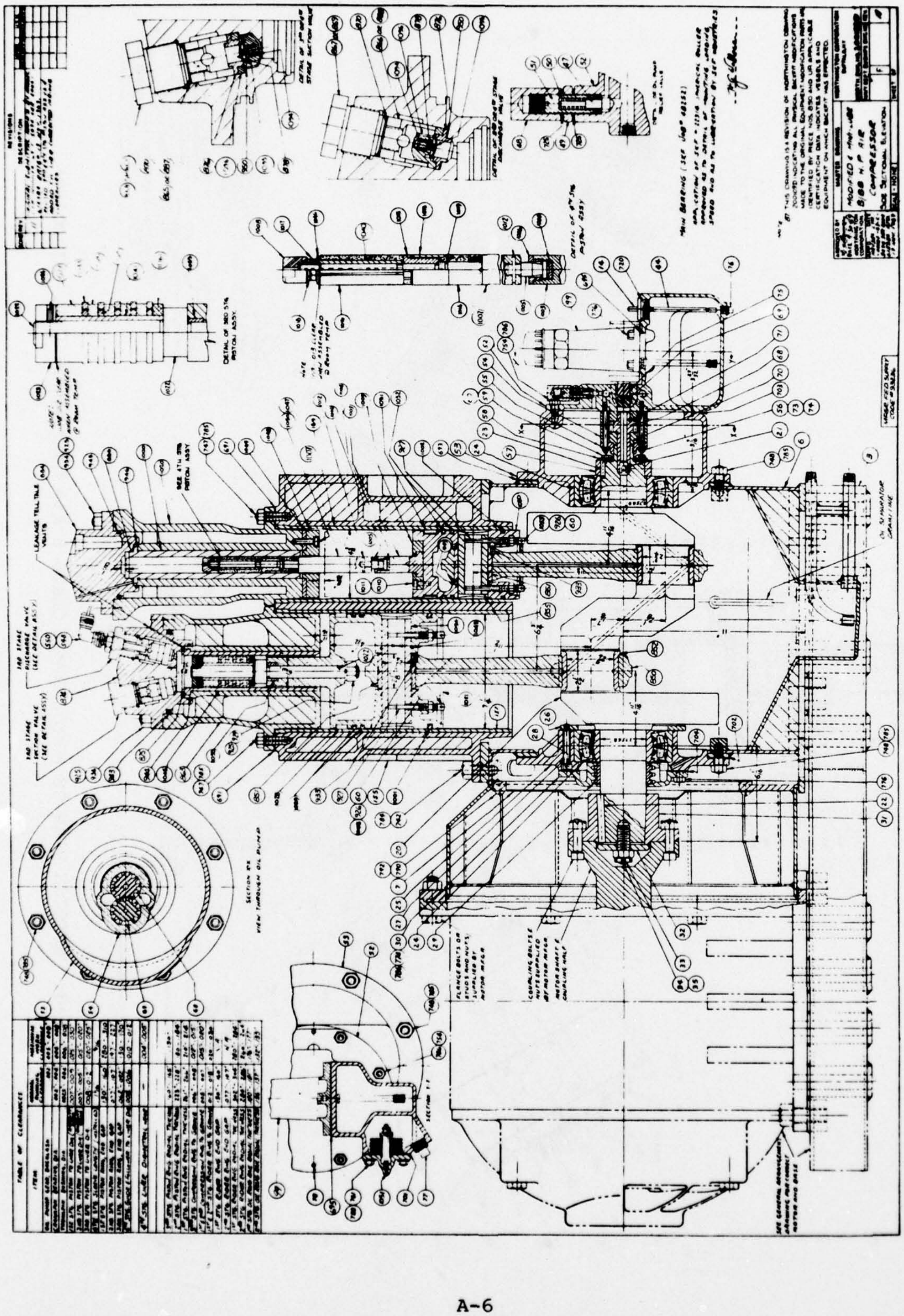


Figure A-4. SECTION VIEW OF WORTHINGTON CLASS B/BB AIR COMPRESSOR (APL 061900338)

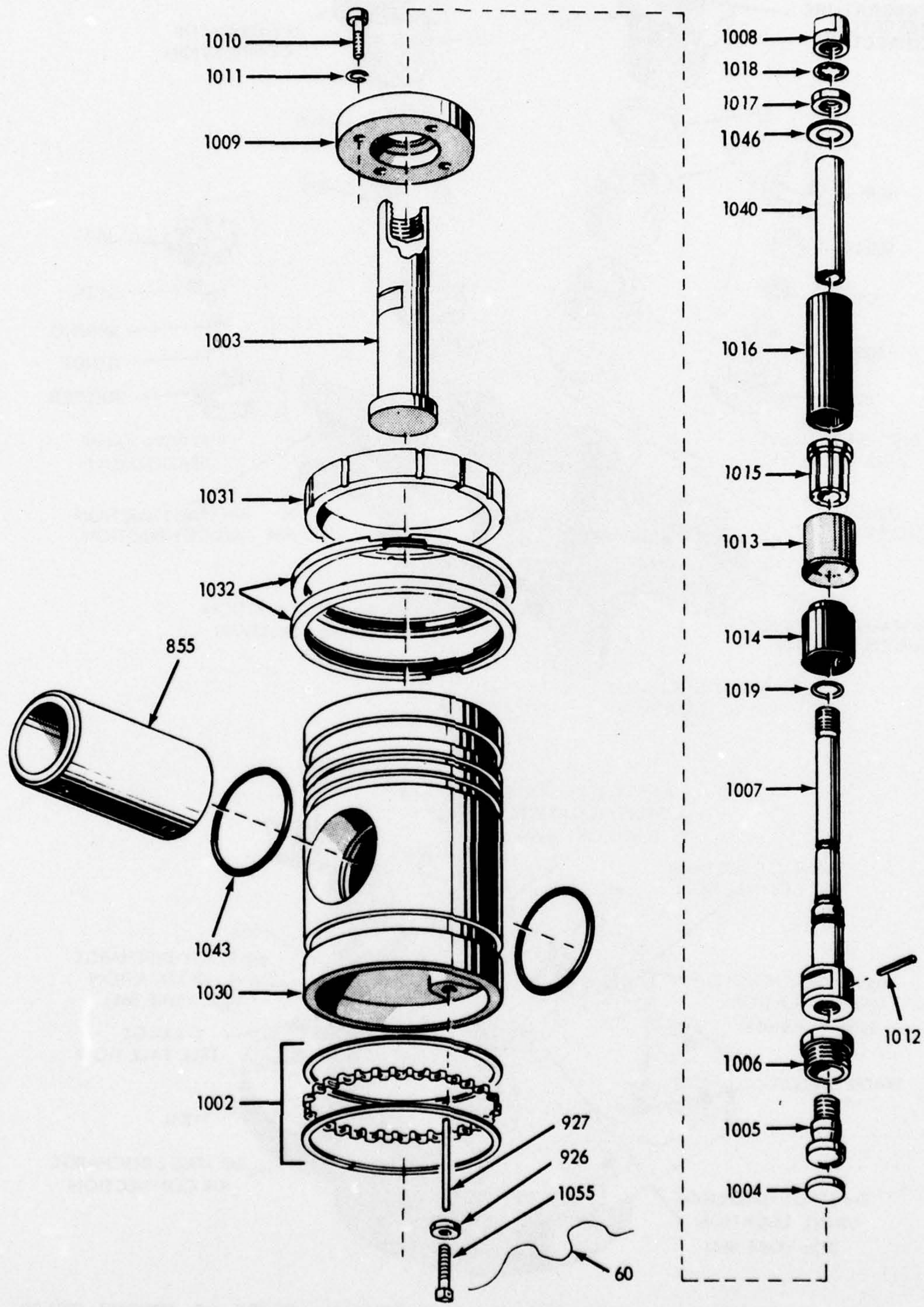


Figure A-5. SECOND- AND FOURTH-STAGE PISTON ASSEMBLIES FOR WORTHINGTON H.P.A.C. (APL 061900338)

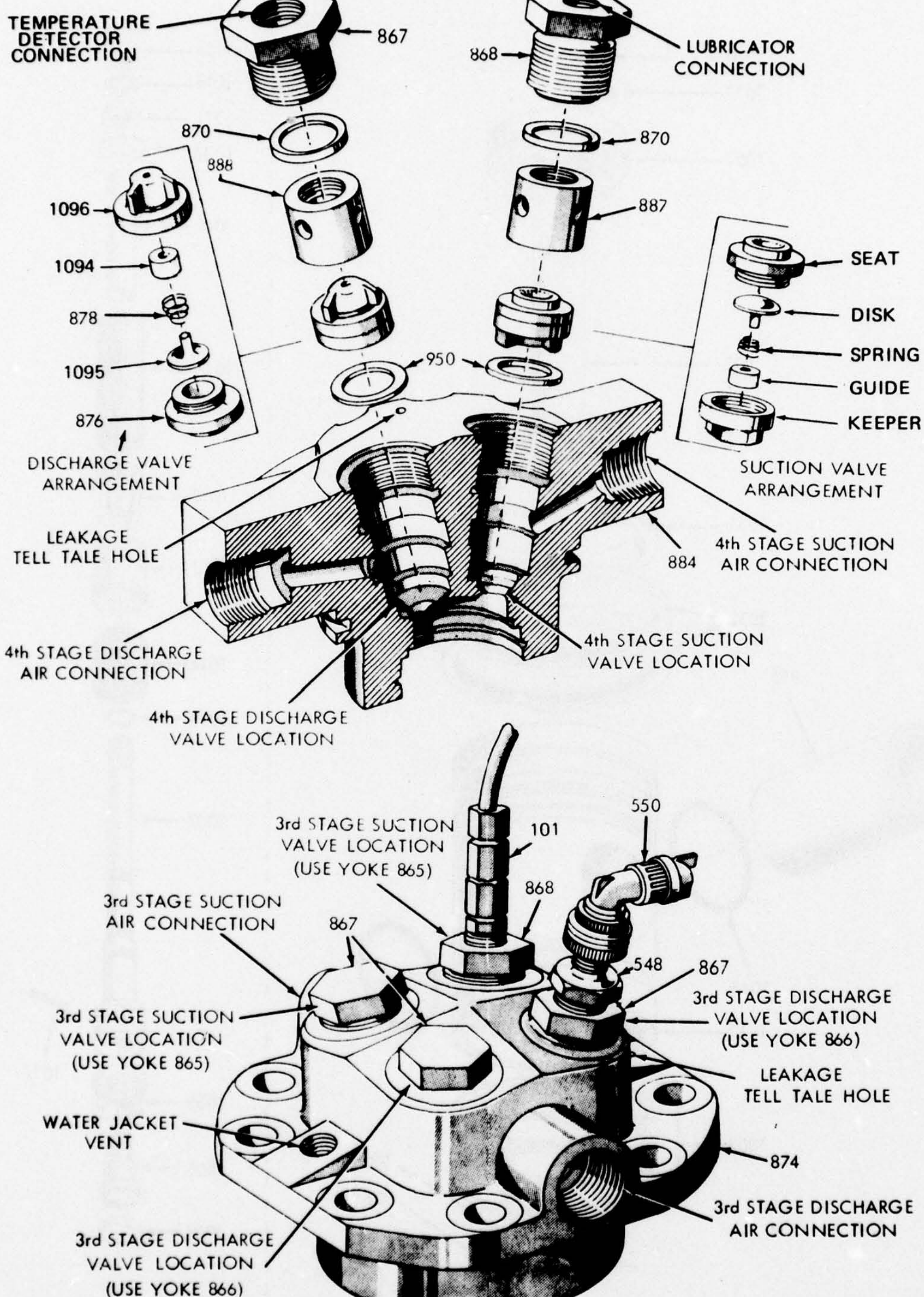


Figure A-6. SUCTION AND DISCHARGE VALVE ASSEMBLY, THIRD OR FOURTH STAGE, FOR WORTHINGTON H.P.A.C. (APL 061900338)

Table A-1. CONFIGURATION DATA FOR MAJOR INSTALLED COMPRESSED AIR SYSTEM EQUIPMENTS

Nomenclature	APL/CID	Quantity by Hull Number									
		DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
* L.P. AIR COMPRESSOR											
Compressor Air L.P. 50 CFM 100 PSI	061900179			5				5	5		
Compressor Air L.P. 100 CFM 125 PSI	061900359	4	4		4	4	4			4	4
Motor AC 440V 15HP	174750561			5				5	5		
Motor AC 440V 30HP	175504876	4	4		4	4	4			4	4
Starter Motor SZ 2	151203576			3				4	4		
Starter Motor SZ 2	151209322			2				1	1		
Starter Motor SZ 3	151406514	4	4		4	4	4			4	4
L.P. AIR SYSTEM PIPING											
Pressure Reducing Station	440200002	4	4	1	4				2		2
Pressure Reducing Station	440200003			1							
Pressure Reducing Station	440200007								2		
Pressure Reducing Station	440200008									3	2
Pressure Reducing Station	440300001	4	6							4	4
Pressure Reducing Station 6 SCFM	440300004	1	3							1	2
Pressure Reducing Station 6 SCFM	440300007	2	4							2	2
Pressure Reducing Station	440300015										1
Pressure Reducing Station	440300016										1
Pressure Reducing Station	440300017										2
Pressure Reducing Station 1.2 SCFM	440300021			1	1	1	1	1	1		
Pressure Reducing Station 3.5 SCFM	440300022			1	1			1	1		
Pressure Reducing Station 4.0 SCFM	440300023			1	2	1	1	2	2		
Pressure Reducing Station 4.5 SCFM	440300024			1	1			1	1		
Pressure Reducing Station 5.6 SCFM	440300025			1	1	1	1	1	1		
Pressure Reducing Station 8.0 SCFM	440300026			3	2	2	2	1	2		
Pressure Reducing Station 12.5 SCFM	440300027			2	2	2	2	2	1		

*Critical Equipment List Item

(continued)

Table A-1. (continued)											
Nomenclature	APL/CID	Quantity by Hull Number									
		DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
* DEHYDRATOR											
Compressor RFG Semihermetic	060250047		2		2	2	2	4		2	
Compressor RFG Semihermetic	060250087									4	4
Condensing Unt. Rfgt.	324060012		2	2	2	4	2	4	2	2	
Dehydrator Fltr. 30 SCFM	440140013								1		
Dehydrator Fltr. 30 SCFM	440140015			1							
Dehydrator Fltr. Rfgt. 30 SCFM	440140024		2							2	
Dehydrator Fltr. Rfgt. 30 SCFM	440140026	2									
Dehydrator Fltr. Rfgt. 36 SCFM	440140031							2	2		2
Dehydrator Fltr. Rfgt. 30 SCFM	440140032										2
Dehydrator Fltr. Rfgt. 100 SCFM	440140051	4									
Dehydrator Fltr. DSSC 30 SCFM	402000001		2	1	2			2	2		2
Dehydrator Fltr. DSSC 30 SCFM	440200009			1							
Dehydrator Fltr. DSSC 30 SCFM	440210002			1							
Dehydrator Fltr. DSSC 30 SCFM	440210004	2									
Dehydrator Fltr. DSSC 30 SCFM	440210027	4									
Dehydrator Fltr. Rfgt. 36 SCFM	440300010	2								2	
Dehydrator Fltr. Rfgt. 30 SCFM	440300014		2	2	2	4	2	2	2	2	
Dehydrator Fltr. Rfgt. 100 SCFM	440300032					4				4	4
* H.P. AIR COMPRESSORS											
Compressor Air HIP 5.0 CFM 4500 PSI	061900183				1	1				1	2
Compressor Air HIP 4.5 CFM 4500 PSI	061900266	2	1		1		1	2		1	
Compressor Air HIP 4.5 CFM 4500 PSI	061900338		1	2		1	1		2		
Motor AC 440V 25HP	174750612	2	2	2	2	2	2	2	2	2	2
Starter Motor SZ 2	151202979	2	2	2	2	2	2	2	2	2	2
Lubricator MDL PS-4 4FD RTY DR	650050003		1	2	1	1	1	1	2	2	2

*Critical Equipment List Item

(continued)

Table A-1. (continued)											
Nomenclature	APL/CID	Quantity by Hull Number									
		DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
H.P. AIR COMPRESSORS (Continued)											
Lubricator MDL PS-4 4FD RTY DR	650050005	2	1		1	1	1	2			
H.P. AIR PIPING											
Meter FLRT IND FLO TY SZ 6	383530038	2									
Meter FLRT IND FLO TY	383530041		1								
Filter FD Press	480060254					2					1
Filter FD Press	480060293	4	2	2	2						
Filter FD Press	480060305				2						
Filter FD Press	480060342										2
Filter FD Press	480060360						2				
Filter FD Press	480060398			2							
Filter FD Press	481290006	2	3	2	2		2	2	2	2	2
Strainer Y .375 IN	759990002	1	2	1						1	
Strainer SGL .375 IN	750220001	5	5	5	5	5	5	5	5		
Strainer SGL .375 IN	750220053									5	5
Valve Red .50 IPS 4590-5610 PSI	883115132	1									
Valve Red .37 IPS 993-1200 PSI	882112209				1		2	1			
Valve Red .37 IPS 300-500 PSI	882113647						1				
Valve Red .37 IPS 801-1000 PSI	882113649		1	1							
Valve Red .37 IPS 2001-2200 PSI	882113652	2	2	2						2	2
Valve Red .37 IPS 3001-4000 PSI	882113654	1	1	1						1	
Valve Red .37 IPS 2000-4000 PSI	882113952					2					
Valve Red .37 IPS 2106-3600 PSI	882117116		1		1				1		
Valve Red .37 IPS 1801-2400 PSI	882117117				3	3	4	3	4		
Valve Red .37 IPS 200-2400 PSI	883112152	1									
Valve Red .25 IPS 150-200 PSI	882117635		1			1		1	1	1	

(continued)

Table A-1. (continued)

Nomenclature	APL/CID	Quantity by Hull Number									
		DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
H.P. AIR PIPING (Continued)											
Valve Red .25 IPS 4501-5499 PSI	882117636		1			1		2	2	1	
Valve Red .25 IPS 1100-5500 PSI	882118914										2
Valve Red .25 IPS 1-25 PSI	883111875							1		1	
Valve GLB DPHRM CONT .75 IPS 250 PSI	882240420	2	2	2	2	2	2	2	2	2	2
Valve SPCL STP .37 IPS 5-2995 PSI	882240221				2						
Valve COMBN RED X STP .37 IPS 632-1062 PSI	882240393		1	1	1		1	1			
Manifold 10 VL RED HIP 4500 PSI	882352013		1	1	1		1	1	1	1	
Manifold 5 VL RED HIP 5000 PSI	882352017			2	2		2	2	2		
Manifold 5 VL RED HIP 5000 PSI	882352318	1									
Manifold 4 VL .37 IPS	882351176										1
Manifold 6 VL .25 IPS	882351323	2						1		1	1
Manifold 5 VL .25 IPS	882351324	2						1		1	1
H.P. AIR DEHUMIDIFICATION UNIT											
Dehydrator Fltr. DSCC 26 CFM	440110005		1								
Dehydrator Fltr. DSCC 10 CFM	440130001					1		1			
Dehydrator Fltr. DSCC 20 CFM	440130005										1
Dehydrator Fltr. DSCC 10 CFM	440130022		1	2	2		2	1	1		
Dehydrator Fltr. DSCC 27 SCFM	440270001	2						1		1	1

APPENDIX B

MDS PARTS USAGE SUMMARY

Table B-1 summarizes usage data on significant part replacements in high-burden system components of the Compressed Air Systems. The screening criteria are discussed in Section 2.3 of Chapter Two. Included in the table are the total number of parts replaced and the ratio of parts replaced to total population. During the MDS data period, the low pressure air compressors on 7 of the 10 ships of the Class were replaced and 6 of 10 ships had one or more of their high pressure air compressors extensively modified. The figures shown in the Total Parts Population column are those of the highest parts population that existed at any time during the MDS data period.

It is assumed that the MDS data base contains records on nearly all the parts replaced, i.e.; the number of parts replaced without requisitions or MDS documents over the analysis period was insignificant.

TABLE B-1. SIGNIFICANT PARTS USAGE

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
NSN	Nomenclature							
Worthington Air Compressor (APL 061900179)								
1H-4310-00-052-5005	Liner - LP Cyl	304	2	100	43	43	19	5
1H-4310-00-052-5007	Liner - HIP Cyl	304	1	50	32	64	18	6
9C-3110-00-100-4414	Bearing-RLR TPR 2.8750	22	1	50	30	60	24	9
9C-4310-00-141-9818	Ring-PSTN LP CMPRS	2	4	200	424	212	66	10
9C-4310-00-141-9819	Ring-PSTN HIP CMPRS	2	2	100	285	285	67	10
9C-4310-00-142-0174	Ring-PSTN HIP Oil	2	2	100	322	322	79	10
9C-4310-00-142-0175	Ring-PSTN LP Oil	3	4	200	508	254	78	10
9C-3110-00-158-8404	Bearing-RLR TPR 2.8750	26	1	50	23	46	20	7
9Z-5340-00-281-6715	Ring-RET LP PIN	1	4	200	97	48	17	9
9Z-5340-00-282-6349	Ring-RET LK PIN HIP	1	2	100	70	70	17	8
9Z-3120-00-288-4477	Bearing-SLV	3	2	100	49	49	23	9
9C-4310-00-308-7112	Spring-SUCT UNL RETN	1	3	150	55	36	22	8
9C-4310-00-349-6746	Piston Assy HIP	102	1	50	13	26	11	6
9C-4310-00-580-9506	Bearing-SLV LP Wrist PIN	2	2	100	95	95	34	10
9C-4310-00-580-9524	PIN-PSTN HIP Wrist	10	1	50	43	86	24	8
9C-4310-00-580-9525	PIN-PSTN LP Wrist	8	2	100	80	80	30	8
9C-4310-00-619-0485	Spring-HLCPS Suct Unl Pwr	1	3	150	34	22	13	8
9C-4310-00-629-1737	PIN-CONROD	14	2	100	81	81	27	8
9C-4310-00-626-1739	Piston-COMPR LP	65	2	100	31	31	13	5
9C-4310-00-626-1758	Strip-VL COMP	1	72	3600	8012	222	71	10
9C-4310-00-626-1760	Bearing-SLV CONROD Link	7	2	100	77	77	32	10
9C-4310-00-626-1762	Bearing-SLV HIP Wrist PIN	11	1	50	53	106	33	10
9C-4310-00-626-1769	Bearing-SLV	18	1	50	89	178	53	10
9C-4310-00-626-1774	Pump-RTY PWRDN	223	1	50	14	28	11	6
9C-4310-00-526-1777	Rod Assy-CONN	418	1	50	11	22	8	4
9C-4310-00-626-1778	Valve Assy-DSCHG	157	3	150	39	26	13	6
9C-4310-00-626-1779	Valve Assy-Suct	90	3	150	34	22	13	7
9Z-3120-00-661-6028	Bearing-SLV ADPTR	10	1	50	27	54	20	9
1H-4310-00-670-7687	Crankshaft-COMPR	689	1	50	22	44	17	7
9Z-3120-00-794-2714	Bearing-SLV OP DR GR	6	1	50	30	60	21	7

(continued)

TABLE B-1. (Continued)

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
NSN	Nomenclature							
9C-3030-00-899-3838	Belt-V MTCH Set	10	1	50	134	268	31	9
Worthington Air Compressor (APL 061900183)								
1H-9515-00-035-7535	Valve Strip	2	24	480	369	77	19	8
1H-4310-00-097-5929	PIN-PSTN	30	1	20	11	55	4	3
1H-4310-00-097-5930	Trunk-PIN-2nd STG	18	1	20	4	20	4	3
1H-4310-00-131-2413	Ring-PSTN SRPR 2nd STG	12	1	20	22	110	21	7
1H-4310-00-131-2901	Ring-PSTN Oil 2nd STG	5	1	20	31	155	24	8
1H-4310-00-131-2902	Ring-PSTN Oil 1st STG	9	1	20	24	120	20	8
1H-4310-00-131-2905	Ring-PSTN 1st STG	10	2	40	39	98	21	7
1H-4310-00-141-9816	Ring-PSTN 1 1-4 4th STG	2	1	20	38	190	22	7
1H-4310-00-141-9826	Ring-PSTN 1 1-4 4th STG	5	11	220	234	106	23	8
1H-4310-00-173-5264	Ring-PSTN SNAP 2nd STG	5	3	60	53	88	20	7
1H-4310-00-173-5265	Ring-PSTN SRPR 1st STG	14	1	20	22	110	20	7
1H-4310-00-216-8010	Liner-1st STG Cyl	473	1	20	7	35	7	5
1H-4310-00-216-8011	Liner-2nd STG Cyl	396	1	20	9	45	8	5
1H-4310-00-216-8015	SLV-Cyl Liner 4th STG	976	1	20	15	75	15	7
1H-4310-00-218-3956	Valve-1st & 2nd STG	112	6	120	55	46	17	7
1H-4310-00-218-3957	Valve HIP 3rd & 4th STG	8	6	120	162	135	28	7
1H-4310-00-218-3997	Bushing-PIN	40	2	40	13	33	8	5
1H-4310-00-218-4010	Socket - HPPSTN	6	1	20	9	45	5	3
9C-4310-00-218-4013	Seat-VL 3rd & 4th STG	6	6	120	53	44	16	8
1H-4310-00-218-4014	Keeper - 3rd & 4th V1	15	6	120	60	50	17	8
1H-4310-00-218-4015	Disk - 3rd & 4th V1	5	6	120	159	132	37	8
1H-4310-00-218-4016	Adapter - V1	32	3	60	25	42	13	3
1H-4310-00-218-4117	Piston 1st & 3rd	306	1	20	6	30	6	4
1H-4310-00-218-4118	Piston x Rod 2nd STG	813	1	20	9	45	8	4
1H-4310-00-218-4119	Piston 4th STG	376	1	20	36	180	28	6
9Z-3120-00-661-4966	Bushing-SLV OP IPL SHFT	2	2	40	12	30	7	5
9Z-3120-00-661-8444	Bearing-SLV OP DR SHFT	14	2	40	14	35	8	5
1H-4310-00-679-5334	Head-Cyl Compr 4th STG	407	1	20	9	45	9	5
1H-4310-00-679-5337	CLY-SLV Liner 3rd STG	190	1	20	9	45	9	6
1H-4310-00-679-5338	Gear-SHFT SPUR OP	81	1	20	7	35	7	6
1H-4310-00-679-5339	Gear-SHFT SPUR OP IDL	38	1	20	5	25	5	4

(continued)

TABLE B-1. (Continued)

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
NSN	Nomenclature							
2H-4310-00-825-2041	Crank Shaft	893	1	20	7	35	4	3
9Z-3110-00-830-1657	Bearing-RLR SELF ALGN	46	2	40	26	65	14	6
1H-4310-00-967-4802	Bearing-Half-SLV	42	2pr	40	12pr	30	6	3
9C-4310-00-999-9916	Ring-PSTN 3rd STG	4	6	120	144	120	24	7
Worthington Air Compressor (APL 061900266)								
1H-9515-00-035-7535	Valve Strip	3	24	192	348	181	16	4
1H-4310-00-131-2901	Ring-PSTN Oil 2nd STG	6	1	8	29	362	15	4
1H-4310-00-131-2902	Ring-PSTN Oil 1st STG	10	2	16	25	156	14	4
1H-4310-00-173-5265	Ring-PSTN SRPR 1st STG	14	1	8	8	100	5	3
1H-4310-00-216-8010	Liner-1st STG CYL	473	1	8	6	75	6	3
1H-4310-00-216-8011	Liner-2nd STG CYL	396	1	8	4	50	4	3
1H-4310-00-216-8015	Sleeve-CYL	976	1	8	19	237	16	4
1H-4310-00-300-6051	Spring-HLCPS VL	2	6	48	45	94	11	4
1H-4310-00-623-8754	Seat-UNL-VL 1st & 2nd	5	1	8	7	88	6	2
1H-4310-00-623-8756	Seat-4th STG UNL VL	15	3	24	18	75	6	3
1H-4310-00-623-8759	Valve-UNL	25	4	32	35	109	7	3
1H-4310-00-659-6625	Spring-HLCPS	3	4	32	21	66	5	3
1H-4310-00-659-6627	Piston-1st & 2nd STG UNL	14	2	16	8	50	4	2
1H-4310-00-659-6627	Piston-3rd STG UNL	21	1	8	9	113	5	2
1H-4310-00-659-6628	Piston-4th STG UNL	24	1	8	7	88	6	3
9Z-3120-00-661-4966	Bushing-SLV OP IDL SHFT	2	2	16	5	31	3	3
9Z-3120-00-661-8444	Bearing-SLV OP DR SHFT	4	2	16	4	25	2	2
9Z-4310-00-679-5337	Cylinder-SLV 3rd STG	190	1	8	9	113	8	3
1H-4310-00-679-5338	Gear-SHFT SPUR OP	81	1	8	3	38	3	3
1H-4310-00-679-5339	Gear-SHFT SPUR OP IDL	38	1	8	3	38	3	3
9C-5940-00-725-1699	Seat-VL	13	6	48	42	88	12	3
9C-4310-00-782-7818	Ring-PSTN 1st STG	5	2	16	32	200	16	4
9C-4310-00-782-7826	Ring-PSTN 2nd STG	5	3	24	60	250	20	4
2H-4310-00-825-2041	Crankshaft	893	1	8	2	25	2	2
1H-4310-00-872-6378	Head-4th STG CYL	648	1	8	4	50	4	2
9C-4310-00-873-4975	Collar-End PSTN	7	2	16	12	75	6	5
9C-4310-00-875-8249	Spacer-PSTN	4	7	56	59	105	9	5
9C-4310-00-875-8252	Ring-SEP 4th STG PSTN	7	6	48	59	123	11	5

(continued)

TABLE B-1. (Continued)

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
NSN	Nomenclature							
9C-4310-00-967-4802	Bearing-Half-SLV	42	2pr	16	25	156	13	5
1H-4310-00-967-4817	Piston-CMPRS	1570	1	8	4	50	4	4
1H-4310-00-967-4818	Piston-CMPRS 2nd & 4th STG	679	1	8	11	138	11	4
1H-4310-00-967-4819	Ring-PSTN 3rd STG	5	6	48	97	202	19	4
1H-4310-00-967-4820	Ring-PSTN 4th STG	4	7	56	182	325	25	6
Worthington Air Compressor (APL 061900338)								
1H-4310-00-218-3956	Valve 1st & 2nd STG	112	6	42	21	50	5	3
9C-4310-00-237-3570	Ring-SE 1st STG PSTN	79	2	14	4	29	2	2
9C-4310-00-237-3574	Ring-SE 3rd STG PSTN	4	5	35	14	40	3	2
9C-4310-00-237-3575	Ring-PSTN 1st STG Oil	18	1	7	4	57	4	2
9C-4310-00-238-5360	Ring-PSTN 2nd STG Oil	14	1	7	4	57	4	2
9C-4310-00-444-1747	Sleeve-4th STG PSTN	279	1	7	14	200	10	2
9C-4310-00-444-1748	Sleeve-FLWR	97	1	7	8	114	7	2
9C-4310-00-444-1752	Liner-4th STG CYL	113	1	7	2	29	2	2
1H-3120-00-967-4801	Bushing-SLV	60	2	14	4	29	2	2
9Z-3120-00-967-4802	Bearing-Half-SLV	42	2pr	14	12	86	7	2
Worthington Air Compressor (APL 061900359)								
9C-3030-00-313-1048	Belt-V Set of 3	16	1 set	28	7	25	6	2
9C-4310-00-339-0690	Liner-HIP CYL	388	1	28	6	21	3	2
9Z-5360-00-480-3340	Spring-Suct UNL	2	3	84	8	10	3	2
9Z-3120-00-480-3472	Bearing Half Set SL	32	1 set	28	9	32	5	3
9C-4820-00-482-4195	Insert-Valve Strip	1	128	3584	895	25	7	3
9C-4820-00-482-4201	Valve Assy LP Suct	219	2	56	12	21	8	2
9C-4310-00-482-4447	Ring-LP Rider	19	2	56	18	32	7	3
9C-4310-00-482-4449	Ring-HIP Rider	19	1	28	7	25	5	2
9C=4310-00-482-4465	Ring-LP Compr	18	4	112	37	33	8	2
9C-4310-00-482-4466	Ring-HIP Compr	16	3	84	42	50	11	3
9Z-5330-00-487-5998	Seal Guide PSTN Seal x 2 rings	18	6	168	66	39	8	3
9Z-5330-00-710-8488	Ring Oil Seal	10	6	168	54	32	7	2

(continued)

TABLE B-1. (Continued)

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
NSN	Nomenclature							
9Z-3110-00-763-0258	Bearing-Main	17	2	56	12	21	4	2
9Z-3110-00-763-0380	Bearing-Roler-NEEDL	6	6	168	42	25	3	3
Dehydrator FLTR RFGT 30 SCFM (APL 440300014)								
9G-6645-00-412-8633	Timer-Interval	96	1	16	3	19	3	3
9C-4810-00-421-7186	Valve-SOL	57	2	32	12	38	8	3
9C-4440-00-421-9579	Diaphragm	7	1	16	5	31	3	2
9C-4540-00-444-1849	Heater Element	100	2	36	39	122	15	5
9C-4440-00-444-1850	Ball-CHK	1	2	32	29	90	10	5
9N-5930-00-448-2633	Switch-Press	67	1	16	6	38	5	4
9C-4820-00-469-7794	Valve-CHK	18	2	32	25	78	10	4
9C-4820-00-471-8531	Valve-CMBR	115	1	16	6	37	5	3

APPENDIX C

CASREP SUMMARY ANALYSIS

CASREPs submitted against the Ship's Service (Low Pressure) and the High Pressure Air Systems for the DDG-37 Class, covering the period 1 July 1973 through 30 September 1977, were analyzed to determine the types of critical failures experienced by the system. Ninety-two CASREPs were submitted in this period. The results of the analysis are listed in Table C-1, with the data categorized by equipment and by type of failure.

To determine the rate of CASREP submissions against the system, the total number of CASREPs was divided by the total DDG-37 Class ship operating years during the data period. Thus

$$\frac{\text{Number of CASREPs}}{\text{Ship Operating Years}} = \frac{92}{3.15} = 2.9 \text{ CASREPs per Ship Operating Year}$$

Table C-2 summarizes categories of CASREPs reported for the Compressed Air Systems analyzed and lists the number of each category experienced by ships of the DDG-37 Class.

Table C-3 provides information on the required correction time associated with system CASREPs. Correction time is divided into maintenance time and time awaiting parts. The data indicate that the system was "CASREP'd" awaiting parts (Not Operationally Ready Supply - NORS) for approximately 53 percent of the total CASREP time.

Table C-1. CASREP SUMMARY ANALYSIS				
Equipment/Component	Reported Failure Modes	CASREPs Reported		Number of Ships Reporting
		Number	Percent of Total	
Low Pressure Air Compressor (APL 061900179)		28	31	7
o Oil Pump Seal Failure	1			
o Main Bearing Failure				
oo Misalignment	3			
oo Unknown	3			
o Cracked Cylinder Liner	1			
o Motor Grounded				
oo Insulation Deterioration	1			
oo Moisture	3			
o Thermostatic Switch Failure (High Temperature Shut-Off)	1			
o Crankshaft Failure	1			
o Unknown	4			
o 3-Way Solenoid Valve Failure	1			
o Unloader Failure	2			
o Water In Lube Oil				
oo Head Gasket Failure	2			
oo Personnel Error	1			
oo Unknown	1			
o Cracked Piston Rings	1			
o Lube Oil Pump Failure	1			
o Pully Retaining Hub Split	1			
Low Pressure Air Compressor (Non-Lube) (APL 061900359)		10	11	3
o Drain System Solenoid Valve Failure	4			
o Unloading Valve Failure	1			
o Needle Bearing Failure	1			
o Link Pin Failure	1			
o Water Pump Gasket Failure	1			
o Motor Shorted	1			
o Cooling Water Reg. Valve Failure	1			
High Pressure Air Compressor (APL 061900183)		8	9	5
o Unknown	2			
o 4th Stage Piston Ring Failure				
oo Defective Lubricator	1			
oo Unknown	1			
o Unloader Failure	2			
o Air Blowback to 2nd Stage				
oo Worn Cylinder Liner	2			

(continued)

Table C-1. (continued)

Equipment/Component	Reported Failure Modes	CASREPs Reported		Number of Ships Reporting
		Number	Percent of Total	
High Pressure Air Compressor (APL 061900266)		12	13	4
o Normal Wear	1			
o 4th Stage Piston Ring Failure	4			
o 2nd & 4th Stage Piston Ring Failure	2			
o Crankshaft Failure				
oo Misalignment	1			
o Worn Cylinder Liners (1 & 2 Stage)	1			
o 3rd Stage Suction Valve Leaking	1			
o 4th Stage Piston Failure	1			
o Main Bearing Failure	1			
High Pressure Air Compressor (APL 061900338)		15	16	4
o Unknown	3			
o Personnel Error	1			
o 4th Stage Piston Seal Failure	3			
o Main Bearing Failure	1			
o Normal Wear	2			
o 4th Suction & Discharge Valve Failure				
oo Carbonization	1			
o Cylinder Lubricator Failure	2			
o 4th Stage Cylinder Failure	1			
o Air Blowback into 2nd Stage	1			
Dehydrator Filter Rfgt (APL 440300014)		9	10	4
o Motor Burned Out	2			
o Timer Unit Failure	1			
o Step-Down Transformer Failure	1			
o Heating Element Failure	4			
o Air Leak	1			
Dehydrator Filter Rfgt (APL 440300032)		3	3	1
o Separators Leaking	2			
o Compressor Siezed	1			
Dehydrator Filter Rfgt (APL 440140051)		1	1	1
o Transformer Shorted	1			
Dehydrator Filter DSCC (APL 440270001)		1	1	1
o Check Valve Failure	1			

(continued)

Table C-1. (continued)				
Equipment/Component	Reported Failure Modes	CASREPs Reported		Number of Ships Reporting
		Number	Percent of Total	
Dehydrator Filter Rfgt, 36 SCFM 150 PSI (APL 440300010)		2	2	1
o Heating Element Failure	2			
Starter Motor Size 2 (APL 151209322)		1	1	1
o Main Contract Coil Shorted (Moisture)	1			
Monitor Alarm Temperature Indicator (APL 385110001)		1	1	1
o Relay K-6 Failure	1			
Valve Reducing .37 IPS, 3600 PSI (APL 882095556)		1	1	1
o Dome Pressure Leaking	1			
Total		92	100	

Table C-2. COMPRESSED AIR SYSTEMS, DDG-37 CLASS CASREPS, 1 JULY 1973 - 30 SEPTEMBER 1977

APL	Nomenclature	Quantity of Reports by Hull Number										
		37	38	39	40	41	42	43	44	45	46	Total
061900179	Low Pressure Air Compressor Class CC	3	4	4	6	1		7	3			28
061900359	Low Pressure Air Compressor Non-Lube Class S		2				2				6	10
016900183	High Pressure Air Compressor Class B-BB		1		1		2			2	2	8
016900266	High Pressure Air Compressor Class B-BB	2	3					3		4		12
061900338	High Pressure Air Compressor Class B-BB		1	6			3		5			15
440300014	Dehydrator Filter Rfgt 30 SCFM 120 PSIG		3	3				1	2			9
440300032	Dehydrator Filter Rfgt 100 SCFM 150 PSIG						3					3
440140051	Dehydrator Filter Rfgt 100 SCFM 100 PSIG										1	1
440270001	Dehydrator Filter DCSS 27 SCFM 5000 PSI	1										1
440300010	Dehydrator Filter Rfgt 36 SCFM 150 PSIG									2		2
151209322	Starter Motor SZ 2			1								1
385110001	Monitor Alarm Temp Ind.							1				1
882095556	Valve Red. 37 IPS 3600 PSI									1		1
Totals		6	14	14	7	1*	10	12	10	9	9	92

*USS KING (DDG-41) experienced only 8 ship operating months during the CASREP reporting data period.

Table C-3. CASREP CORRECTION TIME

APL	Nomenclature	Days Down			Number CASREPs	Average Day		Percent Down Due To	
		Total	Maintenance	Supply		Down Per CASREP	NORS Per CASREP	Maintenance	Supply
061900179	Low Pressure Air Compressor Class CC	1537	1029	508	28	55	18	67	33
061900359	Low Pressure Air Compressor (Non-Lube) Class S	516	338	178	10	52	18	66	34
061900183	High Pressure Air Compressor Class B-BB	599	389	210	8	75	26	65	35
061900266	High Pressure Air Compressor Class B-BB	949	552	397	12	79	33	58	42
061900338	High Pressure Air Compressor Class B-BB	1084	180	904	15	72	60	16	84
440300014	Dehydrator Filter Rfgt 30 SCFM 120 PSIG	223	27	196	9	25	22	11	88
440300032	Dehydrator Filter Rfgt 100 SCFM 150 PSIG	210	6	204	3	70	68	3	97
440140051	Dehydrator Filter Rfgt 100 SCFM 100 PSIG	61	6	55	1	61	55	10	90
440270001	Dehydrator Filter DCSS 27 SCFM 5000 PSI	26	0	26	1	26	26	0	100
440300010	Dehydrator, Filter Rfgt 36 SCFM 150 PSIG	46	3	43	2	23	21	7	93
151209322	Starter Motor SZ 2	34	3	31	1	34	31	9	91
385110001	Monitor Alarm Temp Ind.	71	33	38	1	71	38	46	54
882095556	Valve Red. 37 IPS 3600 PSI	131	1	130	1	131	130	1	99
	Total	5487	2567	2920	92				
	System Averages					60	32	47	53

APPENDIX D

SHIPALT SUMMARY

The following ShipAlts are applicable to the DDG-37 Class Compressed Air Systems and are not yet complete throughout the class (Table D-1, at the end of this appendix, summarizes the status of completion of the alterations as reported in SAMIS):

1. DLG-6-0116D: Improve Lubrication to High Pressure Air Compressors

Purpose: To reduce operating and maintenance attributed to inadequate lubrication by the installation of Modification Kit.

Work Requirements:

- Install the following material provided by the Modification Kits furnished by NAVSHIPS:
  - High-feed-rate cylinder lubricator
  - New design lubricator check valve
  - New design cylinders, cylinder heads, and pistons
  - New high pressure air valves
  - A third-stage moisture separator
  - An automatic moisture separator drain system

2. DLG-6-0184K: Install Elapsed Time Meters and Events Indicators on High Pressure Air Compressors

Purpose: To provide a method for determining compressor operating time for use in scheduling maintenance.

Work Requirements: Install elapsed time meters and events indicators for the two Worthington High Pressure Air Compressors

3. DLG-6-0341D: Modify Power Distribution System to Low Pressure (LP) and Combustion Air Compressors

Purpose: To connect the combustion control air compressors and the ship service low pressure air compressors to the emergency power distribution system.

Work Requirements: To connect the combustion control air compressors and the ship service low pressure air compressors to the emergency power distribution system, perform the following work:

- Disconnect cable [3-68-1-4P-A(1)] that runs from power panel 3-68-1 to ship service and combustion control compressor No. 1; reconnect this cable to the spare circuit breaker in power panel 3-88-1 and properly designate this circuit
- Disconnect cable [3-11202-4P-A(1)] that runs from power panel 3-112-2 to ship service and combustion control compressor No. 3; reconnect this cable to the spare circuit breaker in power panel 3-132-2 and properly designate this circuit.
- Retain the circuit breakers in power panels 3-69-1 and 3-112-2 and designate them as spares

Summary/Miscellaneous Comments: This ShipAlt does not apply if ShipAlt DLG-6-1055, "Replace Low Pressure Air Compressor/Install Dryer", has been accomplished.

4. DLG-6-1055K: Replace Low Pressure Air Compressor/Install Dryer

Purpose: To increase the low pressure air capacity and improve reliability, maintainability, and quality.

Work Requirements:

- In Fire Room No. 1 (5-68-O-E) and Fire Room No. 2 (5-112-Aft-O-E) accomplish the following:
  - Remove two refrigifilter type dehydrators
  - Remove five 50 scfm, Low Pressure Air Compressors on ships that have not received the AAW modernization
  - Remove the fifth low pressure air receiver from the ships that received the AAW modernization
  - Install four 100 scfm oil free low pressure air compressors and four Type I dehydrators
  - Modify the existing salt water cooling system to suit new compressors and dehydrators
- Provide electric power supplies for new compressors and dehydrators, including electrical interlocks from a vital source
- Ensure that compressors supply air to their receivers via their Type I dehydrators. Receiver by-passes are required.

Interrelated Items: ShipAlt DLG-6-1098, "Electronic Dry Air Modifications", must be accomplished prior to or concurrently with this ShipAlt; it establishes a vital service main, installs receiver automatic drain valves and low-point drains.

5. DLG-6-1098K: Electronic Dry Air Modifications

Purpose: To provide a more effective and reliable electronic dry air system and to separate vital from nonvital air users.

Work Requirements:

- In Fire Room No. 1 (5-68-O-C) and Fire Room No. 2 (5-112-Aft-O-E) replace the existing electronic dry air dehydrators with new improved types
- Rearrange low pressure air system so as to establish a vital main, protected by priority valves and supplied by all compressors -- all vital air users to be supplied by this main; all nonvital air users to be supplied by the nonvital main
- Install system low-point drains and receiver automatic drain valves; install dehydrator and vital main alarms

Interrelated Items: ShipAlt DLG-6-1055, "Install Low Pressure Air Compressor/Dryers", installs four 100 scfm oil-free low pressure air compressors, receiver bypasses, and Type I dehydrators.

6. DLG-6-1170D: Air Dehydrator Modification Kit

Purpose: To improve the efficiency and reliability of Howell Laboratories, Inc. Low Pressure Air Dehydrator by installation of modification kit.

Work Requirements: Install modification kit to the Howell Laboratories, Inc. Low Pressure Air Dehydrator, Type III, Model 3780.

Summary/Miscellaneous Comments: This ShipAlt will provide for improvements to the dry air system pending installation of new dehydrators by ShipAlt DLG-6-1098K, "Electronic Dry Air Modifications".

7. DDG-37-1177K: "Replace Electronic Air Dryer with Type 2"

Purpose: To improve the operating efficiency and reliability of the electronics dry air system by replacing the older, less efficient units with Type 2 units.

Work Requirements: The work requirements for this ShipAlt are not defined at this time.

8. DDG-37-1206K: Replace High Pressure Air Compressor

Purpose: To improve high pressure air compressor reliability, maintainability, and quality by installing oil-free air compressors.

Work Requirements: The work requirements for this ShipAlt are not defined at this time.

Table D-1. STATUS OF ALTERATIONS

ShipAlt Number	Status by DDG Hull Number									
	37	38	39	40	41	42	43	44	45	46
0116D	C	C	C	A	C	C	C	C	C	C
0184K*	C	C	C	C	C	C	C	C	C	C
0341D	C	C	A	C	C	C	C	A	C	C
1055K	C	C	A	C	C	C	B	A	C	C
1098K	C	A	A	B	A	A	B	A	C	A
1170D	N	A	A	B	A	C	C	A	A	N
1177K	A	N	N	N	N	N	N	N	A	N
1206K	A	A	A	A	A	A	A	A	A	A

Legend: A - Approved for accomplishment but not yet funded
B - Funded for accomplishment
C - Completed
N - Not Applicable

*See Section 3.2.2 for additional status information on this alteration.

APPENDIX E

MRC EVALUATION

The DDEOC MRC Evaluation form in this appendix specifies the Maintenance Index Pages (MIPs) applicable to the Compressed Air Systems, lists the Maintenance Requirements Cards (MRCs) that should be modified or deleted, and indicates where new MRCs are needed.

The column headings of the DDEOC MRC Evaluation form are explained as follows:

- MRC Title - Description of maintenance specified by MRC.
- MRC Number - Identification number of MRC.
- Responsibility - Organizations responsible for change (if any).
- Current Status - (self-explanatory).
- Man-Hours - Personnel time burden allotted to complete maintenance evaluation.
- Frequency - When the MRC maintenance action is to be performed, e.g., D = daily, W = weekly, M = monthly, U2M - every two months, A = quarterly, S = semiannually, A = annually, C = once every cycle, R = as required.
- Type - Perform maintenance (P), or survey material condition of component (S).
- Who Performs Test - Maintenance action or test to be performed by tender, DDEOC Site Team, or Ship's Force personnel.
- Where performed - (self-explanatory).
- Data - Indicates whether data are recorded during performance of maintenance action.

DDEOC MRC EVALUA

MRC TITLE	MRC NUMPER	RESPONSIBILITY		CURRENT STATUS			MAN-HOURS		FREQUEN	
		NAVSEA	DDEOC	OLD WITH NO CHANGE	OLD WITH REVISION	NEW	PRE-DDEOC M/H	POST-DDEOC M/H	PRE-DDEOC	POS
<u>Low Pressure Compressed Air Piping System - MIP TBD</u>										
1. Inspect air flasks, separators, and piping.	To Be Assigned	X				X		TBD		
<u>High Pressure Air Compressor MIP A-3/55-27</u>										
1. Renew element in High Pressure Air Line Filter	36-J76D-Y	X			X		1.0	1.0	R-12	A
2. Clean and inspect 1st, 2nd, 3rd, and 4th stage Air Compressor Piston Rings (APLs 061900183 and 061900266).	To Be Assigned	X				X		TBD		
3. Inspect 4th stage Seal Assembly (APL 061900338)	To Be Assigned	X				X		TBD		
4. Clean and inspect cylinder lubricator check valves	84-E45K-N	X			X		3.2	3.2	R-6	
5. Inspect Cooling Water Shutoff Valve	84-E45N-Y	X			X		5	5	R-11	
6. Inspect and renew Zinc Anodes	To Be Assigned	X				X		TBD		
7. Clean and inspect 3rd and 4th Stage Valve Assemblies	27-L48D-N	X			X		4	4	R-2	
<u>High/Medium Pressure Compressed Air Piping System - MIP A-700/1-46</u>										
1. Inspect air flask, separators, and piping.	To Be Assigned	X				X		TBD		

*P = PERFORM MAINTENANCE; S = SURVEY INSPECTION

SHIP CLASS: DDG-37

SMA NO: 37-204-551

SYSTEM: Compressed Air Systems

EOC MRC EVALUATION

MAN-HOURS		FREQUENCY		TYPE*	WHO PERFORMS TEST			WHERE PERFORMED	DATA	REMARKS
DDEOC M/H	POST-DDEOC M/H	PRE DDEOC	POST-DDEOC	P-PERF. S-SURV.	TENDER	DDEOC	SHIP	I-IN PORT S-AT SEA	YES NO	
	TBD		S	S			X	I,S	No	To be accomplished every 6 months (required by NSTM Article 9490.151.).
1.0	1.0	R-12	A-12R	P			X	I,S	No	Accomplish annually or after 200 hours of compressor operation, whichever occurs earlier.
	TBD		R	P,S			X	I,S	No	Accomplish every 45 months or 1000 hours of compressor operation, whichever occurs earlier. (This PMS action will require that Ship's Force be assisted by IMA personnel until an adequate shipboard maintenance capability has been developed.)
	TBD		R	P,S			X	I,S	No	Accomplish every 45 months or 1000 hours of compressor operation, whichever occurs earlier.
.2	3.2	R-6	R	P,S			X	I,S	No	Accomplish every 45 months or 1000 hours of compressor operation, whichever occurs earlier.
5	5	R-11	R	P,S			X	I,S	No	Accomplish every 30 months or 500 hours of compressor operation, whichever occurs earlier.
	TBD		R	P,S			X	I,S	No	Accomplish every 30 months or 500 hours of compressor operation, whichever occurs earlier.
4	4	R-2	R	P,S			X	I,S	No	Accomplish every 45 months or 1000 hours of compressor operation, whichever occurs earlier.
	TBD		S	S			X	I,S	No	To be accomplished every 6 months (required by NSTM Article 9490.151.).

APPENDIX F

DDEOC ACTION TABLE

DDEOC action items are presented in the table of this appendix. The table is formatted to provide the implementation status of changes through completion of the Class Maintenance Plan and to serve as a ready reference to specific paragraphs in Chapter Three that address in detail the problem involved.

DDEOC ACTION TABLE

1 ACTION ITEM * a. NO.	b. TITL	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5 RESPO
1.	Baseline Overhaul Requirements				
	A. Repairs and Overhauls				
	Low Pressure Air Compressors		Perform a Class B Overhaul of 4 Worthington oil-free air compressors.	3.5	NAVSEA
	Low Pressure Air Dehydrators (Type III)		Perform a Class B Overhaul of 2 Howell Laboratories dehydrators, overhaul to include replacement of ball check valves.	3.3.2, 3.5	NAVSEA
	Low Pressure Air Dehydrators (Type I)		Inspect installation of ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/ Install Dryers) to determine if false temperature indicator and alarm problems exists, make necessary corrections.	3.3.3.3	NAVSEA
	Low Pressure Air Flasks		Remove, clean, test and preserve low pressure accumulator air flasks.	3.5	NAVSEA
	High Pressure Air Compressors		Perform a Class B Overhaul of 2 Worthington air compressors, overhaul to include installation of "mini-lube" modification kit as applicable.	3.5	NAVSEA
			Install an automatic operating back pressure valve in the air piping system, if not already installed.	3.4.2	NAVSEA
			Provide recommended on-board spares during during SOAP if not previously accomplished.	3.4.2, 3.4.3	NAVSEA
	High Pressure Air Dehydrators (Type II)		Perform a Class B Overhaul of 2 installed air dehydrators.	3.5	NAVSEA
	High Pressure Air Flasks		Remove, clean, inspect and reinstall high pressure air flasks.	3.5	NAVSEA

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION OF

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-204-551

SYSTEM: Compressed Air Systems

DEOC ACTION TABLE

	4 REPORT REFERENCE (PARA.)	5 RESPONSIBILITY †	6 SCHEDULING DATES a. REQD.	b. START	c. COMP.	7 REMARKS, FUNDING IMPLICATIONS, ETC.	8 ACTUAL ACTION TAKEN
	3.5	NAVSEA/TYCOM				This assumes ShipAlt DLG-6-1055K has been accomplished.	
	3.3.2, 3.5	NAVSEA/TYCOM				If ShipAlt DLG-6-1098K or DDG-37-1177K is accomplished, this action not required.	
5K s	3.3.3.3	NAVSEA/TYCOM				This problem is not limited to the DDG-37 Class. Ships in other classes having received a similar ShipAlt have reported this same problem.	
	3.5	NAVSEA/TYCOM					
o	3.5	NAVSEA/TYCOM					
ss- not	3.4.2	NAVSEA/TYCOM				Air Compressors APL 061900338 only.	
ing h-	3.4.2, 3.4.3	NAVSEA/TYCOM					
	3.5	NAVSEA/TYCOM					
	3.5	NAVSEA/TYCOM				Depending on the date of the last inspection this could include up to 5 flasks.	

2

D FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(continued)

DDEOC ACTION TAB

1. ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5. RES
	High Pressure Air Separator Flasks		Remove, clean, inspect 2 air separator flasks; replace those that are obsolete.	3.4.5, 3.5	NAVSE
	Air System Piping (L.P. and H.P.)		Inspect air system for oil contamination and for external corrosion or damage, make necessary repairs and test.	3.5	NAVSE
	B. Alterations				
	Low Pressure Air Compressor		Accomplish ShipAlt DLG-6-1055K (Replace Low Pressure Air Compressor/Install Dryers) if not already completed.	3.5	NAVSE
	Low Pressure Air Dehydrator		Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit)	3.3.2	NAVSE
			Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Mod)	3.3.2	NAVSE
			or		
			Accomplish ShipAlt DDG-37-1177K (Replace Electronic Air Dryers with Type II) as applicable.	3.3.2	NAVSE
	High Pressure Air Compressor		Accomplish ShipAlt DLG-6-0184K (Install Elapsed Time Meters and Events Indicators on H.P.A.C.)	3.2	NAVSE
			Accomplish lubrication low-oil-level shutdown device ShipAlt, when developed.	3.4.2	NAVSE
	Air Line Filters		Accomplish air line filter replacement ShipAlt when it is developed.	3.4.1	NAVSE

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS:	DDG-37
SMA NO:	37-204-551
SYSTEM:	Compressed Air Systems

DEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
e.	3.4.5, 3.5	NAVSEA/TYCOM				Air flasks manufactured to MIL-C-15111 or 51-F-5 are obsolete and need to be replaced.	
on	3.5	NAVSEA/TYCOM					
e	3.5	NAVSEA				Only three ships have not had this alteration installed (i.e., DDG-39, 43 and 44)	
	3.3.2	NAVSEA/TYCOM				These units may be replaced by ShipAlt	
	3.3.2	NAVSEA/TYCOM					
ice ;	3.3.2	NAVSEA/TYCOM					
l tors	3.2	NAVSEA				Headquarter level records this ShipAlt as being accomplished on all ships of the Class; this is in error as determined during ship visits.	
ed.	3.4.2	NAVSEA					
:	3.4.1	NAVSEA					2

ED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(Continued)

DDEOC ACTION TABLE

1. ACTION ITEM* a. NO.	b. TITLE	2. DDEOC EVALUATION**	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6.
2.	Intra-Cycle Maintenance Requirements		No additional action required.			
3.	Follow-On ROH Requirements					
	Low Pressure Air Compressors		Perform Class B Overhaul of 4 Worthington oil-free air compressors.	3.5	TYCOM	
	Low Pressure Air Dehydrators (Type I)		Perform Class C repairs to 4 Type I air dehydrators.	3.5	TYCOM	
	Low Pressure Air Dehydrators		Perform Class C repairs on 2 Type II or 2 Type III air dehydrators.	3.5	TYCOM	
	High Pressure Air Compressors		Perform Class B Overhaul of 2 high pressure air compressors.	3.5	TYCOM	
	High Pressure Air Dehydrator (Type II)		Perform Class C repairs on 2 Type II air dehydrators.	3.5	TYCOM	
	Air Systems Flasks and Separators		Remove, clean, test, preserve and reinstall air system flasks and separators.	3.5	TYCOM	
	Air System Piping		Inspect air system piping for oil contamination and for external corrosion or damage, including leaking valves; make necessary repairs and test.	3.3.3, 3.4.5	TYCOM/SHIP	
4.	Reliability and Maintainability Improvements					
	Low and High Pressure Air Compressors		Develop standard operating logs and provide to Class ships.	3.2.1	NAVSEA	
			Install elapsed time meters and indicators	3.2.2	NAVSEA/TYCOM	
	Low Pressure Air Dehydrator (Type III)		Accomplish ShipAlt DLG-6-1170D (Air Dehydrator Modification Kit)	3.3.2	NAVSEA/TYCOM	

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION OF DEVELOPING

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-204-551

SYSTEM: Compressed Air Systems

EOC ACTION TABLE

2. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
3.5	TYCOM					
3.5	TYCOM					
3.5	TYCOM				These dehydrators supply the Electronic Dry Air System.	
3.5	TYCOM					
3.5	TYCOM					
3.5	TYCOM				Not all air flasks will require the maintenance action at every ROH.	
3.3.3, 3.4.5	TYCOM/SHIP					
3.2.1	NAVSEA				Sample log is available in SMMSO Maintenance Benefit Recommendation #12-75.	
3.2.2	NAVSEA/TYCOM					
3.3.2	NAVSEA/TYCOM				May be replaced by ShipAlt 1098K or 1177K.	

FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(Continued)

DDEOC ACTION TABL

1. ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5. RES
4.	Reliability and Maintainability Improvements (cont)				
	Low Pressure Air Dehydrator Type III) (Cont)		Replace the polyethylene ball check valve.	3.3.2	NAVS SHII
			Accomplish ShipAlt DLG-6-1098K (Electronic Dry Air Modification) or DDG-37-1177K (Replace Electronic Air Dryer with Type II) as applicable.	3.3.2	NAVS
	Low Pressure Air Dehydrator Type I)		Determine if a false temperature indication and alarm problem exists.	3.3.3	NAVS
	High Pressure Air Compressors		Install "mini-lube" modification kit.	3.5	NAVS
			Install automatic operating back pressure valve.	3.4.2	NAVS
			Develop ShipAlt to install an automatic compressor shutdown device controlled by the oil level in the cylinder lubricator oil reservoir.	3.4.2	NAV
	Air Line Filter		Develop ShipAlt to replace current air line filter with a unit that requires less effort to change filter elements.	3.4.1	NAV

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION (

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS:	DDG-37
SMA NO:	37-204-551
SYSTEM:	Compressed Air Systems

EOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
e.	3.3.2	NAVSEA/TYCOM/ SHIP				Accomplish via AER.	
id	3.3.2	NAVSEA					
	3.3.3	NAVSEA/TYCOM				This problem is connected with the installation of ShipAlt DLG-6-1055K. This problem has also been reported in other ship classes (i.e., FF-1052, DDG-2).	
	3.5	NAVSEA/TYCOM				This is required with APLs 061900183 and 061900266 only.	
re	3.4.2	NAVSEA/TYCOM				Air compressor APL 061900338 only.	
y r	3.4.2	NAVSEA					
	3.4.1	NAVSEA					

D FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(Continued)

DDEOC ACTION TABL

1 ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5 RESP
5.	Planned Maintenance System (PMS) Changes				
	High Pressure Air Compressor		Develop a PMS action to clean and inspect the 1st, 2nd, 3rd, and 4th stage air compressor piston rings every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier.	3.4.2	NAVS
			Develop a PMS action to inspect the 4th stage seal assembly after every 1000 hours of compressor operation or after 45 calendar months, whichever occurs earlier.	3.4.2	NAVS
			Modify MRC R-6 (84-E45K-N: Clean and Inspect Cylinder Lubricator Check Valves) to accomplish every 1000 hours of compressor operation or 45 calendar months, whichever occurs earlier.	3.4.2	NAVS
			Modify MRC R-2 (27-L48D-N; Clean and Inspect 3rd and 4th Stage Valve Assemblies) for accomplishment after 1000 hours of compressor operation or 45 callender months, whichever occurs first.	3.4.4	NAV
			Develop a PMS action to inspect and renew, as necessary, the air compressor zinc anodes every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.	3.4.3	NAVS
	Cooling Water Shut-Off Valve		Change the periodicity of MRC R-11 (84-E45N-Y, Inspect Cooling Water Shut-Off Valve) to every 500 hours of compressor operation or 30 calendar months, whichever occurs earlier.	3.4.3	NAVS
	Air Line Filter		Change the periodicity of MRC R-12 (36-J-76D-Y: Renew Element in High Pressure Air Line Filter) to accomplish annually or after 200 hours of operation, whichever occurs earlier.	3.4.1	NAVS
	Air System		Develop a PMS action to inspect the air system for corrosion & damage every 6 mo.	3.3.3, 3.4.5	NAVS

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION O

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37
SMA NO: 37-204-551
SYSTEM: Compressed Air Systems

EOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES			7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
			a. REQD.	b. START	c. COMP.		
ct ar	3.4.2	NAVSEA				Applies to APLs 061900-183 and 061900266 only. This could be scheduled for SRA accomplishment.	
rs	3.4.2	NAVSEA				Applies to APL 061900-338 only.	
s)	3.4.2	NAVSEA					
	3.4.4	NAVSEA				Applies to APL 061900-183 and 061900266 only.	
or	3.4.3	NAVSEA					
ss-	3.4.3	NAVSEA				Applies to APL 882240-420	
	3.4.1	NAVSEA					
o.	3.3.3, 3.4.5	NAVSEA					

D FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(Continued)

DDEOC ACTION TA

1. ACTION ITEM* a. NO.	1. ACTION ITEM* b. TITLE	2. DDEOC EVALUATION**	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5.
6.	Industrial Facility Improvements		None		
7.	IMA Improvements		None		
8.	Integrated Logistics Support (ILS) Improvements				
	Low and High Pressure Air Compressors		Provide increased operator training at the shipboard level.	3.4.1, 3.4.2	NA
			Establish air compressor maintenance courses at the Fleet Training Center level.	3.2	NA
			Place additional emphasis on compressed air system operation at MM and BT "A" School.	3.2	CI
	Low Pressure Air Compressors		Ensure that information on the proper replacement air intake filter element is known at the ship level.	3.3.1	NA
			Revise the technical manual for the Worthington Oil-Free Air Compressor (NAVSHIPS 0949-055-9010).	3.3.3	NA
	Low Pressure Air Dehydrators (Type III)		Either update the NavShips *Technical News* article "Modifying and Operating Dehydrators" and republish in the *NAVSEA Journal* or condense it and release it to the Fleet as a Naval message.	3.3.2.2	NA
	High Pressure Air Compressor		Revise APLs 061900183, 061900266, 0619-00338, and 882240420 to provide additional parts support and increased support depth.	3.4.2, 3.4.3	NA
			Modify the EOSS for H.P.A.C. to add a step to check the cylinder lubricator flow rate.	3.4.2	NA

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATIO

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

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DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
at	3.4.1, 3.4.2	NAVSEA/TYCOM					
	3.2	NAVSEA,CNET				Corrective action has already been initiated by the DART Program to establish these courses.	
sed "	3.2	CNET					
r t is	3.3.1	NAVSEA/TYCOM				COMNAVSEASYSCOM MSG R05145Z APR 77 provided this information to TYCOMS	
	3.3.3	NAVSEA				Corrective action has already been initiated by the DART Program.	
News	3.3.2.2	NAVSEA				Article first published in August 1972	
19- tion- rt	3.4.2, 3.4.3	NAVSEA					
a r	3.4.2	NAVSEA				Procedure HPAC/013	2

IRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

(continued)

AD-A057 826 ARINC RESEARCH CORP ANNAPOLIS MD F/G 15/5
DESTROYER ENGINEERED OPERATING CYCLE (DDEOC), SYSTEM MAINTENANC--ETC(U)
JUN 78 P W JONES N00024-78-C-4062
UNCLASSIFIED 1652-03-18-1763 NL

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DDEOC ACTION TABL

1. ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5 RESP
8.	Integrated Logistics Support (ILS) Improvements (continued)				
	High Pressure Air Compressor (continued)		Advise compressor operating personnel of the recommended cylinder oiling rates.	3.4.1	NAVS
	High Pressure Air Dehydrators		Provide those ships of the class having Kahn and Company high pressure air dehydrators with technical manuals for these units.	3.4.5	NAVS
	High Pressure Air Separator Flasks		Increase the availability of replacement high pressure air separator flasks that meet MIL-F-22606 (NSN 1H-2090-00-148-1042).	3.4.5	NAVS
	Cooling Water Shut-Off Valve		Monitor the operation of the latest design of this valve (D53X) to determine if the changes have improved this valve's performance.	3.3.3.2	NAVS
			Monitor the tests at NSRDC to determine if the "modified" cooling water shut-off valve is an improvement over the existing valves. If the valve is a significant improvement, modify all the valves, via AER, as they fail.	3.4.3	NAVS
	Air System		Develop Material Condition Assessment (MCA) procedures for the Compressed Air Systems.	3.5.3	NAVS

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† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-204-551

SYSTEM: Compressed Air Systems

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
ël of es.	3.4.1	NAVSEA/TYCOM				Recommend the action be accomplished by an article in "Contact" and "Quarterly Information Bulletin".	
ying for	3.4.5	NAVSEA/TYCOM				APL 440130022	
ement that 3-	3.4.5	NAVSEA/SPACC				NAVSEA is aware of the problem, and corrective action is in progress.	
de- ne if e's	3.3.3.2	NAVSEA/TYCOM				This task could be assigned to the DDEOC Site Teams.	
ine -off sting nt via	3.4.3	NAVSEA/TYCOM				NSRDC point of contact: Mr. John Braden (301) 267-3542.	
t Air	3.5.3	NAVSEA				Draft MCA procedures have already been developed for the H.P. Air System on the FF-1052 Class ships.	

IRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.